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THE PRODUCTION OF LIGHT BY ANIMALS.*

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INTRODUCTION.

ORGANIC life, as we understand it, appears to be a product of the latter part of the existence of cosmic bodies. After some unknown beginning as a heated mass, such a body cools until the higher temperatures have fallen far toward the absolute zero, and then a crust is formed by the crystallization of some of the varied elements present, and, among these, certain elements unite to form the bodies of organized beings; of plants and animals.

These plants and animals are to be looked upon, from one narrow point of view, as self-sustaining and self-perpetuating machines that are constantly releasing energy; and they perform this work in spite of the fact that they are also engaged in adding properly proportioned and elaborated masses to their own bodies as well as secreting part of their substance into the form of materials that are to be thrown off and used outside of the body for purposes useful to the organism.

The energy released is also in the forms that are most useful

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to the organism. Sometimes it is hidden in chemical changes whose products are to be used at some future time; and in this case a certain portion of the energy, a very small residue, appears as a by-product, consisting of electricity, or heat, or motion; perhaps sometimes even of light.

At other times, however, the energy is produced in an active form and in large quantities, as motion, or heat, or electricity, or light, and is developed in tissues or organs specialized for the purpose and in quantities which in most cases suffice for the performance of duties that are of real use to the life of the organism. Thus, motion is produced in useful amounts, as in the cat, or gull, or squid; heat, as in the bee or bird; electricity, as in the *Gymnotus* or *Torpedo;* and light, as in the fire-fly, or fish, in worms, and other lower forms of life.

The number of organisms which possess the powers of releasing energy in the four forms mentioned above has an interesting relation to the values that the forms of energy possess as factors in the life of the organism. Motion is of such paramount importance in any creature's life, especially if it be an animal, that we find it to be of almost universal occurrence. Even if we fail to consider the physical movements that occur in the cell and its organs, or the motion of growth, we still can hardly name any animal that does not require a considerable output of motion for its continued existence. The organ of motion, the muscle-cell, occurs as a familiar feature in sections of almost any animal body. In smaller kinds the ciliated cell is more abundant, and even in some larger animals the surfaces covered with such cells generate large and strong currents of water or streams of mucus.

Next in importance to motion I should place the generation of heat. It is true, of course, that our present seats of life on the earth's surface are all more or less heated to a point above the absolute zero; usually to a point somewhere from freezing-point up to the neighborhood of 100° F. And, certainly, vast numbers of creatures live normal lives in these temperatures, or even outside of them, without having the power to materially raise their own internal temperature above their surroundings. Still, I think all will acknowledge that most of the best and more interesting forms of life have acquired the power of producing this important form of energy within their bodies so as to keep them at a fixed temperature that is usually much above the surrounding media in

which they live. A few insects and nearly half of the large group of vertebrates are about the only animals that have this power. This indicates a rather narrow distribution of heat production in the animal kingdom, but it also shows a distribution among the most important part of this kingdom, as well as among a very large number of species. Further, it is a consistent distribution: where one species of a genus possesses it, so do all the others in nearly every case. It indicates to some degree a phylogenetic relationship.

The most narrow distribution of energy production is found in the case of the power to produce electricity. This seems to be restricted to the fishes alone, although it is always possible that some of the constantly recurring reports of its existence in some invertebrate forms may some time prove to be true. It is confined not only to the fishes, but to only certain groups of them, to certain more or less widely separated genera or families which show no genetic relationship to each other, so far as their electric powers are concerned.

Lastly, we find the power of releasing energy from the body in the form of light. As in the case of electricity production, this power shows an irregular and eccentric distribution. It is a much wider allotment than in the case of electricity, nearly all the larger groups of animals as well as many of the plants showing some single member or several members that can shine in the dark. Still, it remains true that most animals can emit no light, that the largest number depend on other sources than their own bodies for the light by which they see, perform photosynthesis; or which they use as an ornament, a threat, or an attraction to the creatures around them. Were the luminous species counted it would more than probably be found that they constituted less than one per cent. of the known forms of life.

The manner in which human attention is attracted to this light in organisms is a matter of interest. To the natural wonder excited by its rarity is usually added the mystery of darkness and usually the imaginative stimulus of the sea or the country and woods in which most of the light exhibitions take place. Under such circumstances the accounts brought in by the average traveller are exaggerated, and further inaccuracy is assisted by the fact that in observing such an animal by night one sees only the light and cannot observe the creature that produces it except with

great difficulty. It takes a certain kind of moral courage to leave a cosey fireside or comfortable cabin and go out in the dark, not only to see the lights, but also to capture the animals that produce them and study the manner of their production in anything like a scientific way.

Thus the production of light, like the production of electricity, is not accepted as a normal fact by most people. It does not enter into their personal lives in the same way that heat and motion do, and when brought to their notice it is regarded as "wonderful" and incomprehensible, although motion is a more complex and more wonderful form of energy production than any one of the other three.

The appearance of light, then, shining out of an animal's flesh and taking its origin in that flesh, is a spectacle that is well calculated to produce wonder. And where wonder comes, curiosity is aroused and questions will be asked. Is the light caused by phosphorus? Why does it not burn the fire-fly? Is it hot? How is it controlled? etc., are but a few of the queries that a thoughtful person will imagine on the spot when a worm, or mollusk, or echinoderm is exhibited glowing or flashing in the dark, and the following series of papers are but a crystallization of the writer's researches and reading in an effort to answer many of these questions.

As a method of presentation it has been deemed possible to treat of the light-producing power by beginning with the plants and lower animal forms and describing the higher groups in turn, using each group as a basis for the explanation of certain of the several principles that appear to govern the processes. Finally, some of these general truths will be made the subject of special chapters in which they can be more fully discussed.

THE BACTERIA.

It seems fitting that some species of that great primitive group of organisms, the bacteria, should be endowed with the light-producing power. Such is the case, and we find some of the most interesting exhibitions of luminosity displayed by these minute organisms. They have served, too, for the demonstration of some of the more important truths concerning light production by investigators in this field. Nowhere else can we find the various physiological functions of life in so simple a condition and so clearly divorced from morphological structure. Certain known

features of structure, such as the marked external membrane and other possible but unknown segregations of protoplasmic material, undoubtedly condition the formation of materials and performance of functions, but here, if anywhere, we can feel or even prove that in the same uniform flesh all the different life functions take place and all the substances that bacteria secrete and handle are formed in the same undifferentiated protoplasm.

The bacteria are a group of organisms that are so small in size that we find it hard to classify them on their morphological structures. It is true that they are sometimes labelled and arranged according to their shape, the possession of flagellæ, of a pellicle, etc., but one of the principal and most important factors used in giving them name and place in a system of nomenclature is what they will *do*. In hardly any other living group will it be possible to find a classification so based on the intrinsic physiology of the forms.

One of the earlier attempts to classify the particular forms of bacteria in question was by constituting a group, the photobacteria, thus frankly grouping them according to whether they produced light or not. It seems probable, however, that this property of giving off light must have originated independently in more than one particular group of bacteria, and such independent origin would at once break up the phylogenetic homogeneity of this arrangement.

Gorham, in 1903, studied many of the forms with great care, and, after consulting the literature on the subject, enumerated some twenty forms, with their synonyms, that he considered as well-described and separate species, and five others that appeared to be doubtful as to their descriptions.

He distinguished, among the twenty, two groups which seemed to have many characters in common, and called them the *Bacillus pflugeri* group and the *Microspira luminosa* group, the first containing fifteen and the second five of the twenty forms that he recognized. He also isolated and studied two forms, from seawater and on mammal-flesh and fish, that belonged one to each group, but did not give these new forms names, saying that they fell in with forms already present in the groups, but not specifying those forms.* The important points in connection with

* Gorham's tables will appear with part two of this article in the December issue of the JOURNAL.

this arrangement are that these two groups do have important structural and physiological differences between them which, if proved by time to be accurate, will divide the photogenic bacteria into two groups of more than generic value. To sum up Gorham's studies, I will quote from him: "It will be noticed that all photogenic bacteria agree in certain particulars. They are all motile under certain conditions, all are provided with one or more terminal flagellæ, none stains by Gram's method, none of them forms spores, none of them ferments sugars according to the method of the Bacteriological Committee. This latter, however, is due to the fact that they are all unable to grow, except very slightly, in solutions containing 1 per cent. of sugar.

"The characteristics of the two groups into which the photogenic bacteria have been divided may be defined as follows: To the *Bacillus pflugeri* group belong those species of larger size and extremely variable form that do not liquefy gelatine at all, or at least but very slowly, and that grow best at a temperature lower than 22° C.; the members of the second group, the *Microspira luminosa* group, are all of small size, liquefy gelatine, and prefer a higher temperature for growth and luminescence."

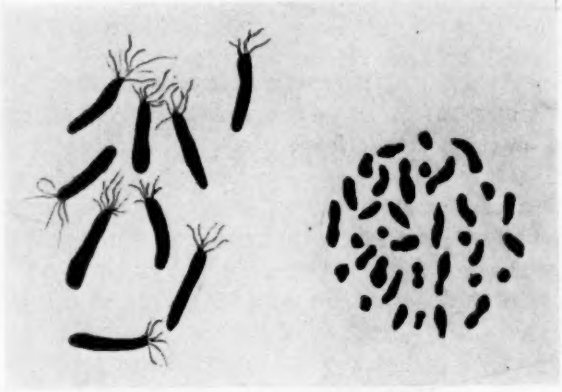
More recently (1907) Molisch has made extensive studies on the light-producing bacteria and arranged them under five generic groups: *Micrococcus, Bacterium, Bacillus, Pseudomonas,* and *Microspira.* To these may be added two forms, *Diplobacterium* and *Vibrio,* more recently described by other authors as containing luminous members. These two latter names do not agree with some of the best modern classifications of bacteria according to Migula.

In form most of the luminous bacteria are more or less elongate, although a few are oval or even round (see Fig. 1). Under dark stage illumination they can be seen as rod-shaped organisms in rapid motion with a quick twisting movement such as is used by mosquito larvæ in moving about. This motion is performed by means of the flagellæ with which they are provided and which carry them on a variable, wandering course with great quickness.

Turning to a systematic classification of the known forms of bacteria as formulated by Migula and as slightly modified by Frost and McCampbell, we find that the seven genera mentioned above do come from different families, although most of them are contained in one more or less compact group. It is to be noted

that all come from a single order, the *Eubacteria*. Thus they contain no sulphur, and in other ways show a lack of certain characters that mark them as a more primitive type, the sub-order *Haplobacteria*, a division designated as the lower bacteria. In this sub-order we find three families, all of which contain some of our luminous forms. The *Coccaceæ* (first family) shows five genera, only one of which has a luminous member, the genus *Micrococcus*. In the second family, the *Bacteriaceæ*, we find three genera, all of which have one or more luminous species among their number. And, lastly, the third family, the *Spirillaceæ*, shows four genera, two of which have luminous members among their genera.

FIG. 1.



Two groups of luminous bacteria as seen fixed and stained on the slide under the highest powers of the microscope. The left-hand forms are some species of the *Bacillus pflugeri* group, and are stained to show the flagellæ. Those to the right are another member of this group stained without showing the flagellæ.

There remains in this order of the *Eubacteria* another entire sub-order, the *Trichobacteria* (higher bacteria), containing four genera, in which no species are reported as producing light; also the entire other order of bacteria, the *Thiobacteria* or sulphur bacteria, containing two families, six sub-families, and far more genera and species than the first order, in which no luminous forms have ever been described.

All these kinds have been classified on the basis of form, chemical constitution, and, more largely, on multiple physiological characteristics, which, taken all together, form a far stronger basis

of classification than the one characteristic of light production. It thus becomes very apparent that luminosity is not a sound basis for the grouping of our light-producing forms, although this power has appeared in a scattered form among those bacteria that are contained in and grouped about the order *Bacteriaceæ*. Thus we must discard the term Photobacteria as applied to a taxonomic group and use it only as a term of convenience in speaking of those various and somewhat scattered forms that can produce light.

The above facts also show that we still need extensive and careful work on the luminous bacteria—work that will serve to identify the different kinds both by peculiarities of their luminous power, as well as by their numerous other reactions, and such characteristics of form and structure as can be discerned under the microscope.

The luminous bacteria do not always glow. For the greater part of their lives they are non-luminous, like other bacteria. They occur in all seas, mostly near or on the bottom or on the beaches, while some are carried inland in various ways and become colonized in marshes, slaughter-houses, or kitchens and in other habitations of man. It is possible that one or more species have become separated from the main group of salt-water forms and become definitely placed as inland species. *Bacillus phosphorens* seems to be such a form. They live and propagate in the small amounts of organic matter in which they are in contact, and, as has been said, they do not produce any light at all under these circumstances of ordinary existence. Many forms are always found living in the slime of the various fishes, mollusks and other creatures of their region.

The natural conditions under which these organisms become luminous have been observed from great antiquity, although the earliest observers did not understand exactly what the significance of the light was. Nor are we sure, from their descriptions, whether they saw a light that was produced by bacteria or by some fungous forms. It was certainly one or the other, however, and we can be fairly sure that in some cases it was a bacterial light.

Already in the days of the Attic intellectual period Aristotle had observed the luminosity of the flesh of dead fish and of domestic animals, and this observation has been repeated from time to time in many ancient writings. Such articles written up to the last century did not mention the fact that this light emanates

from living organism or living tissues. On the contrary, the writers seemed always to believe that it was the result of some form of chemical change due to decay, and various theories were set forth to explain it on that basis. In 1676 Boyle made many observations on the physical and chemical conditions under which the light would exist or would disappear, and some of these were facts which are of real importance at the present time in our studies of the power in various animals. For instance, he showed that air was required to maintain the light, and that when thinned or removed by an air-pump the light ceased, only to be restored when the air was replaced. Among other observers of this period were Paullinus in 1707, Martin in 1761, Hulme in 1801, and Davy in 1810. This latter writer attacked the question in a really scientific manner and investigated the effects of many substances upon the light. Hulme and Dessaugnes independently gave formulæ by which the light could be produced from dead fish mixed with certain chemicals and common substances. The idea that this light is a part of the process of decay still persists in the popular mind to-day, and is undoubtedly a relic of the ideas of these earlier investigators and writers.

At last it began to be suspected that the luminosity was part of the activity of living organisms, and Michaelis, in 1830, expressed a suspicion of this truth. He was followed in 1834 by Ehrenberg, and then in 1854 the physiological chemist Heller advanced the opinion that the light of decaying flesh emanated from some form of low plant, to which he gave the name *Sarcina noctiluca*. In 1875 Pflüger independently came to the conclusion that the light from dead fish was caused by microörganisms, and he experimented to prove that. Collecting some of the luminous slime, he diluted it with sea-water and filtered it. The filtrate was without light, while the residue was still luminous. This proved that the luminous material was not a liquid in this case. He also showed that new preparations of nutrient media could be infected with tiny amounts of the luminous substance, thus bringing fairly good proof that the light did come from living organisms of microscopic size.

From this time on many new and well-trained workers entered the field. Armed with the essential facts discovered by the men mentioned above, they applied all the methods used by bacteriologists as fast as discovered, these methods differing from the

ordinary biological methods in that they dealt for the most part with large masses of individuals, none of which can be submitted to separate study by any satisfactory means beyond observing its shape and motions.

Among the many scientists who have thus studied the luminous bacteria are Nuesch, F. Ludwig, Dubois, Molisch, Beijerinck, Gorham, Migula, Fischer, Lode, Weleminsky, Reitz, Kutscher, Barnard, Percy-Laurent, Driessen, Ehrenberg, Smith, Giard-Billet, E. N. Harvey, and many others.

As a result of the work of the above men we have a fairly good idea of the conditions under which these bacteria will show light. These conditions will be considered presently under the headings of "Oxygen," "Nutrient Media," "Salt" (sodium chloride), "Temperature," etc.

The usual natural conditions under which the luminosity of bacteria are seen are as follows: First, it is often seen on the bodies of fish, mollusks, worms, and other sea animals that have been cast upon the rocks or on beaches and in which decay has begun some short time before. The body must be in some sheltered place where there is some moisture and where the temperature is about that of the sea in that neighborhood. A partial covering of moss or grass assists in preventing drying (which inhibits the bacterial growth) and sun-heating (also unfavorable) between the tides during the day.

On almost any sea-beach one can turn over masses of sea-plants that have been washed ashore near high-water mark, and small bits of glowing matter will be seen among the moist middle and lower layers. Such particles consist most commonly of the bodies or parts of small crustacea and other sea forms that have become infected with the bacteria. The pale greenish light glows steadily and does not waver or go out. It will last for some hours or days if the temperature and moisture are maintained and if an abundant supply of fresh air is supplied.

Or, again, a large fish may lie under a fishing dock, half in the water and in the earliest stages of decomposition (see Fig. 2). On its sides will be seen spots and patches of the same greenish light, and by daylight it can be noticed that those areas which shone in the dark are now covered with a thin but distinct coating of semi-transparent slime. Such patches of light will almost cover the body sometimes, and they disappear as the process of decay

advances. They are never seen when the body becomes really putrid, and they last usually for from two to five days. Any fresh water touching them will quench the light at once, as will also drying, too much heat, or destructive or poisonous chemicals. The light begins with a faint glow, rising to its maximum slowly, and then disappearing quite suddenly as the latter stages of decomposition set in. In this event, of course, many other bacteria, the commoner forms that cause the processes we call decomposition, have multiplied in large numbers, and, besides consuming the

FIG. 2.

Dead codfish lying on the beach under a dock at South Harpswell, Maine. Colonies of luminous bacteria growing on its sides form patches of light when the fish is observed after dark. (Drawing by Bruce Hornfall.)

substances that the luminous forms live and shine on, have cast off many products of their activity that are poisonous to the light-producing forms and that inhibit their luminosity. Among such are many organic acids that acidify the media, and we will see that in an acid medium no light is ever produced.

In few instances does a luminosity appear on bodies that are totally submerged. While it is possible that the bacteria could shine in such a position, for instance, in under-water crannies in the rock or in quiet pools, still the fact has not been observed and published. Also I think it may be stated as a truth that the lum-

inous bacteria of northern seas, while present in most parts of these seas, are never responsible for the general luminosity that we sometimes see in the crests of waves, or on the surf-beaten beaches, or in the wake of a steamer; for it must be remembered always that the bacterial light is a steady one and shines, when it does shine, continuously. It cannot be stimulated by a sudden mechanical shock, or even by electric shock or by heat, from quiescence into activity, as many other forms can.

Gorham reports that in southern seas the bacteria sometimes do cause a general diffused light in parts of the ocean. That a diffusion of bacteria through the sea, while in their proper physiological state for shining, would produce a marked light can be easily seen by mixing an artificial culture of some form like *Bacillus phosphorens* in a large quantity of sea-water. Here we see a glowing fluid with streaks and scums of greater intensity, where the air, owing to movements of fishes or currents, has brought more oxygen in contact with the organisms.

This has been done on the largest scale in the Berlin aquarium, where small quantities of the cultures served to keep the water in large tanks in a state of luminosity for considerable periods. The writer has also used such cultures, mixed with several gallons of sea-water, to illustrate the light-giving power during lectures and demonstrations. Two-tenths of a gramme of centrifuged bacteria in two quarts of sea-water caused a light that enabled one to see faces and read printing at a distance of several feet.

It is doubtful, however, if bacteria ever illuminate large areas of the sea, as do other forms, for any length of time. The principal difficulty would be in finding proper food conditions and in keeping their positions, etc. Nor is it probable that the bacteria illuminate the bottom of the sea at great depths. They probably exist there in the non-luminous condition. They can survive an artificially applied water pressure of over two hundred atmospheres, and it can easily be imagined that they would become accustomed to the abyssal pressure conditions of the ocean deeps. Various proofs exist that these depths are illuminated with a weak light. Creatures with undoubted light-organs assure us that there is some light there. The possession of large eyes fitted for perceiving a very weak light in many deep-sea fishes and crustaceans also points to its more or less universal presence, and, lastly, the use of photographic plates has shown it to be present at consider-

able depths. Still it is very questionable if the bacteria ever show it decidedly in these positions.

The seat of luminous activity of some of the forms of light bacteria is sometimes found in the flesh of domestic animals and other land creatures that have been slaughtered or even prepared for food, as in the form of sausages. These cases have entered prominently into the life of men and groups of men in a way that the previously-mentioned cases have not. Thus we have records involving these cases in legal and religious affairs, as well as in commercial transactions and household affairs. Butchers have lost their trade or even been haled before a court because strings of luminous sausages or luminous cuts of meat have been seen in their shops at night by neighbors or customers. While the writer is in some doubt as to whether this light was always due to bacteria rather than to some fungous form, still we have good authority (Molisch, Heller, Ludwig and Kohlmann, Gorham, etc.) that, in a number of cases at least, the light was due to *Bacterium phosphorens*. In all of these cases it is always true that a considerable quantity of salt had been used in preparing the meat for use, and it is probable that the salt was derived from marine sources and was infected with dormant photogenic bacteria from the sea.

Some few of the luminous bacteria are capable of existing on or in living tissues, or they may even be pathogenic and cause disease. Numerous cases have been reported in which the urine of animals and men has been seen to shine as emitted from the bladder or after being allowed to stand for a short time after. Several species of skunks or polecats (*Viverra mephitis* and *Mephitis lybica*) have been reported in this wise, but there is some question as to whether the light was bacterial or was emitted from the mycelium of a fungus. Also it was possible that bacteria or fungous forms came in contact with the urine after it had been emitted.

So also has human sweat been seen to shine. Many cases have been reported; in particular, an Italian woman was reported by Bartholin, and a Bavarian peasant by Hermbstädt, to be luminous when they perspired freely. In the latter case the luminosity was accompanied by a peculiar smell. The odor was very pronounced in a case reported by Henkel, where it resembled old sauer-kraut. In this case the light was seen best on the shirt freshly drawn from the body, and in daylight it was noticed that the shirt showed nu-

merous and very fine red particles on its surface. Panceri has also reported cases of children in which the skin showed luminosity, especially on spots that had been scratched. In all cases it is probable that light bacteria had found a sufficient medium for growth in the accumulated sweat and filth on the skin, sufficient salt being present in the material to provide conditions under which luminosity could be displayed.

The luminous bacteria sometimes enter into a closer association with living animals. In man they may infect and grow in a wound so that it glows strongly in the dark. Such an infection is not pathogenic, however, and it is said by the military surgeons that such wounds heal better than the others. This statement can be believed when we consider that the luminous bacteria probably occupy space and use nutrient materials that they thus deprive other and possibly pathogenic forms of. Tarcgabiff injected a culture of luminous bacteria into the lymph-sac of a frog, and the infection (perhaps only the original bacteria) spread through many of the creature's tissues. They maintained the luminous state in the tissues for some time, light being seen to glow in the tongue in particular for from three to four days. The animal's health did not seem to suffer, and the bacteria were probably all disposed of eventually by the white blood-cells. Similar experiments would seem to be impossible with the higher vertebrates, as the luminous bacteria will not thrive in such high temperatures.

Some insects and small crustacea are known to become luminous at times owing to the presence of light-producing bacteria in their bodies. In certain of these cases the condition does not result in discomfort or disease to the host. Thus in an expedition to Persia and at other times in Russia and neighboring countries it was observed in swarms of gnats (*Chironomus*) that certain individuals were strongly luminous, while the rest showed no light at all. Owing to their short natural life and delicate structure it was not possible to determine whether this was the harmless presence of the photogenic bacteria in the animal's intestinal canal or if it was a pathological condition. Since the luminous animals seemed to be flying in precisely the same way as the rest of their companions, it was concluded that it was not a case of disease. These facts have been described by Alenizyn, Brischke, Osten-Sacken, Henneberg, Kusnezoff, Schmidt, and others.

On the other hand, observers have noticed that certain crustaceans were often liable to infection by a luminous bacterium that resulted in disease and speedy death. Giard and Billet, De Giaza, Russell, Irwin Smith, and Gorham have made studies of this subject. The original researches of Giard and of Giard and Billet are perhaps the most interesting in this regard. They first observed that many individuals of a species of *Talitrus*, an amphipod crustacean, were infected in this manner and shone in the dark; also, that such individuals died in a few days. Cultures and fresh tissue examinations showed the presence of a micro-örganism or diplo-bacterium which they were able to isolate and keep in sea-water for several days, as well as breed in bouillon media containing the proper amount of sodium chloride. Further, they were able to infect normal *Talitrus* with these bacteria, either from the blood of diseased animals or from the cultures. The infection was performed by cutting off a bit of antenna of the animal to be experimented upon and then applying the diseased tissues to the wounded surface or applying a drop of culture in the same way. The wound healed, but in a period of time between three and four days long the animal began to glow throughout its body, and the light increased slowly, until at the end of four or five days it glowed at its brightest. From this point on the animal showed signs of failing in health and rapidly sickened and died. The failing light continued to glow for some hours after death.

A notable feature of the bacteria was that they would live and multiply in beef and agar media that supported other photo-bacteria in the glowing state, but they would not develop light under those conditions. It was only when living in the blood of the *Talitrus* that they seemed to be able to produce light.

The investigators then tried the experiment of infecting other crustacea with the bacteria and found that nearly allied forms, such as *Orchestia, Hyale, Ligia,* as well as the isopods *Philoscia* and *Porcellio,* could also be infected. In *Orchestia,* for instance, the light took longer to appear—at least seven days. A wounded crab (*Carcinus mœnas*) was also inoculated, and, while the infection did not become general, the wound became luminous and remained so for ten days.

While the luminous bacteria cannot infect a warm-blooded mammal and cause a disease, they can cause its death in a short

time by being injected in sufficient numbers. In this case they probably act as a poisonous material, and the luminosity does not appear to have any influence in the result. Tarchanoff reports the infection of mice and guinea-pigs with *Microspira caraibica* and the resulting death of the animals, but it appears doubtful if these cases were other than a poisoning of the creatures by large numbers of the bacteria being injected at one time. Nor did the animals glow from the presence of the bacteria.

It was discovered at an early date that the photogenic bacteria could be artificially grown and managed much as many other forms can in the laboratory. The early investigators, knowing that the growths usually appeared on fishes, and only on the marine forms, elaborated complicated nutrient media in which the flesh of fishes played a prominent part. Beijerinck, Dubois, and Molisch recommended such formulæ as, for instance, Beijerinck's mixture of sea-water containing 8 per cent. gelatin, 0.5 per cent. asparagin, .1 per cent. glycerine, and 1 per cent. peptone. Other formulæ were still more complicated, as Lode's two mixtures, which, while they did contain the essentials of sodium chloride and a nutrient material and were made faintly alkaline, still were far too cumbersome and unnecessarily exact in details of preparation.

Harvey, using the luminous bacteria from smelt and butterfish, as well as a *pseudomonas*, found that a simple medium of beef peptone, 1 per cent., and glycerine, 1 per cent., mixed in sea-water and made faintly alkaline by a trace of potassium hydroxide, served as an excellent medium for raising large numbers of the microörganism in a vigorously luminous state. Also, by using this same mixture, to which enough agar was added to render it firm, he was able to plate the organisms to secure pure cultures and to make stab cultures in test-tubes.

The fluid cultures produced the bacteria in largest numbers, and an examination of the organisms with dark-stage illumination showed them to be in active motion, undoubtedly by means of their cilia, which could not, however, be seen in such preparations. These cultures were raised in a common refrigerator and were pure cultures secured by plating. A very thin layer of fluid was best because of the large requirement of oxygen, and the organisms grew best on the shallowest edges.

Here the light began to show at the end of 24 hours, and at-

tained its maximum in about two days. After a few days more the light began to wane, until finally it ceased, although the living bacteria were still present.

This disappearance of the light was coincident with the appearance of an acid condition of the medium, due, no doubt, to the presence of acid products of the activity of the organisms. In some cases an infection of the culture with other common forms of bacteria resulted in a much quicker failure of the light, showing that the presence of bacterial activity other than that of light production would inhibit luminosity. In many cases the presence of numerous other bacteria finally resulted in the death of the light-giving forms and their complete elimination from the culture. This is the result in nature when a bit of brightly-shining fish flesh is confined in a closely-stoppered bottle for any length of time.

The luminous bacteria can be centrifuged out of the fluid medium mentioned above and collected in a moist, opaque, yellowish-white, sticky mass, and then kept for a much longer time in a brilliant condition by being shaken up and distributed through some quantity of pure sea-water. If the right quantity of sea-water is used, the bacteria will remain glowing for a number of days, especially if a small amount of the fresh medium is also dissolved in it. Or they can be transferred to a quantity of the fresh medium in shallow plates and allowed to multiply until the acidity of the medium again begins to check their luminosity.

Thus, for purposes of study, a given weight of bacteria can be centrifuged out of a fluid medium and distributed through a given amount of sea-water in a vessel of known shape. At a determined stage of development of the light-producing power and temperature such preparations are the best for studies of the properties of their light.

On the surface of the solid form of the medium, as well as on other solid foods, including the surface of dead fish or bits of fish flesh or other dead organisms, the bacteria go through the same process of an increase in numbers and light-producing power and a decline, due to the increasing acid or poisonous properties of their surroundings. Also, here they cannot so easily be collected and handled.

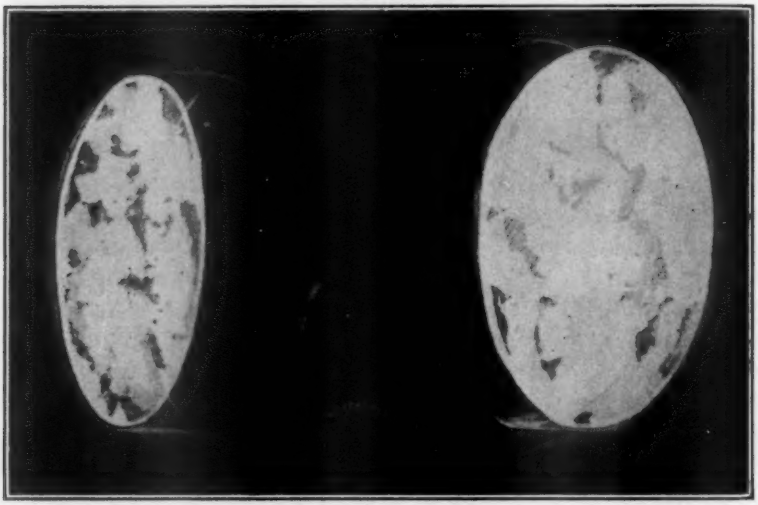
Another method of handling the organism for light investigation is to centrifuge the bacteria out of the food medium and

spread a given weight out over a known surface of filter paper or other solid surface. This method permits of certain experiments not possible with the sea-water method.

Some of the first experimenters used a culture growing on a firm gelatin or agar medium surface for their work (see Fig. 3). This method has great drawbacks, in that the growths of the colonies are progressive and the resulting unevenness does not furnish a good source of light.

The bacteria consume free oxygen in the sea-water very

FIG. 3.



Artificial cultures of luminous bacteria in glass dishes photographed in the dark room. The light from these serves to weakly illuminate a skull, which also shows on the plate. (Copied from Molisch.)

rapidly. Thus if ½ gramme of bacteria is centrifuged out of the nutrient medium and distributed in 100 c.c. of fresh, pure sea-water in a 200 c.c. glass-stoppered bottle, they will shine brilliantly for a few minutes and then all become non-luminous, except a thin film on the upper surface. If now the bottle is shaken several times, the entire mass illuminates again, but again becomes dark when allowed to rest. This indicates that the bacteria are so numerous that they exhaust the free oxygen by their light-producing work and resume it again when more oxygen is supplied.

But if the ½ gramme of solid living bacteria be distributed

in 2000 c.c. of fresh sea-water, they will be so placed that each individual has a sufficient portion of water to furnish free oxygen for several hours, and the mixture will remain glowing for that time.

A very beautiful experiment was performed by Beijerinck, who made a mixture of luminous bacteria and some chlorophyll-bearing algæ and covered the mixture so that no air had any contact with it. After standing a short time in a dark room the light from the bacteria ceased, from lack of oxygen, they having taken the supply of free oxygen out of the water. Then light was admitted to the experiment for a few minutes, and when removed again into the dark the bacteria were once more shining. The cause of their renewed activity in this case was the fact that the light had made possible a photosynthesis by the chlorophyll of the algæ thus liberating oxygen that could be used by the bacteria for light production. Repetitions of the experiment under varying conditions showed that a visible light could be produced for a few seconds by so small an amount of light as the lighting and burning of a single parlor match.

Lode is a scientist with sufficient training in the physics of light to undertake more exact physical measurements of the amount of light emitted by these organisms. He used two forms, *Vibrio rumple* and *Vibrio elvers*, and employed the method of Bunsen to measure the light.

He infected some Petri dishes, small, round, flat, glass dishes, with covers, filled with 20 c.c. of a nutrient agar solution. The dishes were of a size that made a rather thin, wide layer of the agar.

The dishes were then put in an incubator, kept at a proper temperature to allow the bacteria to grow, first in small colonies and later in larger colonies that spread out in patches over the surface of the agar. Selected portions of these colonies were then cut off by a screen with a round hole in it of a given size, and carefully compared with the surface of an opaque, milk-white glass behind which an electric light could be moved backward and forward until its intensity corresponded with that of the bacterial surface.

Comparisons were then made with a German normal paraffin candle, and this was further tested by a Weber photometer.

The results are tabulated on the next page.

Experiment four was selected by Lode as typical of what bacteria can do in producing light, and set forth as follows:

Vibrio rumple.—Intensity per square millimetre—0.000,000,000,785 Hefner candles, which is equal to 0.785 Hefner candle per 1000 square metres, or 0.562 time a German normal candle.

This does not seem to be a very great amount of light, and it is not. Still, the character of the light is such that it acts with a maximum effect on the human retina, as well as, probably, on other eyes in the various animal groups. The light of bacteria

EXPERIMENT.

	Bacteria used, nutrient medium, time of development, and temperature.	Diameter of bacterial surface used.	Light intensity measured in German normal candles.	Actual light intensity of 1 square millimetre of bacterial surface.
1	*Vibrio elvers;* beef peptone agar; 24 hours; 37° C.	0.9 centimetre	0.000,000,056,5	0.000,000,000,076,6
2	*Vibrio rumple;* beef peptone agar; 48 hours; 31° C.	0.8 centimetre	0,000,000,020,049	0.000,000,000,030,6
3	*Vibrio elvers;* codfish peptone agar; 24 hours; 37° C.	0.9 centimetre	0.000,000,262	0.000,000,000,355
4	*Vibrio rumple;* fish peptone agar· 24 hours; 37° C.	2.0 centimetres	0.000,001,287,8	0.000,000,000,785
5	*Vibrio rumple;* fish peptone agar; 24 hours; 37° C.	2.1 centimetres	0.000,001,217	0.000,000,000,707

has been investigated by several competent men, and the position of its wave in the spectrum (*i.e.*, their length) has been determined with the most delicate apparatus. Ludwig, 1884; Hericourt, 1890; Dubois, 1898; Tarchanoff, 1901; Barnard, 1902; Gorham, 1903; Molisch, Forster, Engelmann, Barnard, and MacFadyen are prominent among the many who have studied this light of bacteria.

Many remarks have been made as to the color. All agree that it is a bluish-green, and some use the term "whitish" and "yellowish" also in describing it. Weak colonies appear to show the greenish tint most strongly, while it is concerning the

the strongest shining colonies that the term white is most often heard in describing them. Another important factor in assigning a color is the condition of the human eye at the time of observation. Observers who have been in bright daylight, upon coming suddenly into the dark room and looking at the bacterial colonies will see them as somewhat dimmer and bluer or greener in color than later, when the eyes are accustomed to the darkness. Then the light appears greener or yellowish. An observer who has had a good night's sleep and, without going out into daylight, observes the bacterial colonies in a dark room early in the morning is best fitted to determine the visual properties of the light, and it appears nearer white under these conditions than at any other time.

Direct comparisons of two colonies of bacteria of different species by an eye in good condition show that there are some differences in the "greenness" and "blueness," and that these differences are not always due to greater intensity, as is sometimes the case.

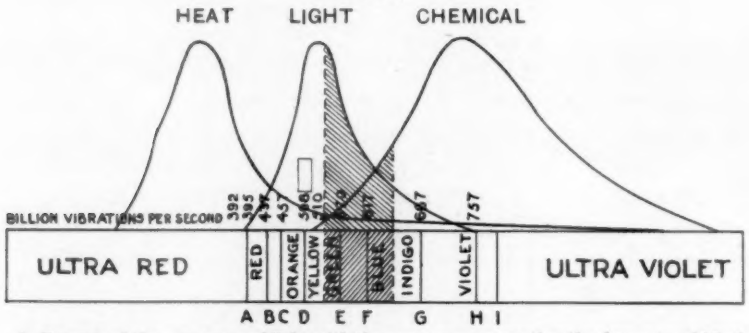
Differences in color are due not only to intensity and to specific dissimilarity but also to the nutrient media on which the colonies are growing at the time. Fischer found that bacteria growing on a medium with the larger proportion of salt gave a light with more blue or green. On the media containing a lesser proportion of salt the tendency was toward a yellowish light. Molisch found that bacteria growing on salted potatoes and human flesh were deeply blue-green, while on dead fish they appeared silver-white. These latter differences seem to be the result of salt proportion and intensity rather than kind of medium. Sufficient work of an accurate nature remains to be done on these favorable organisms with regard to the color of their light.

Gorham has studied the color in the laboratory with physical instruments, and finds that a species secured by him in a butcher shop in Providence, R. I., emits a light with a frequency of vibration ranging from 560,500,000,000,000,000 to 657,600,000,000,000,000 per second. This means that on the spectrum it extends from beyond the line *E* in green to a point midway between *F* and *G* in the blue.

It is continuous within these limits and strongest in the middle part of this extent, becoming weaker at the two extremities of its band.

In Fig. 4 we have a diagram of the three kinds of light as differentiated from each other by their production of heat, their visibility to the eye, and their power to effect chemical change. Or, to put it in another way, we have three curves that show by their rise and maximum point the particular wave-length of light that can do these three things best. The curves cross each other, which means that practically all light waves can do *some* of each. But the maximum points of each curve show that the three effects are still sharply marked off from one another. The shaded area indicates which waves of light are produced by the bacteria, and here we can at once see that the light from these forms is a light that is most able to effect the eye. It is evident that with the

FIG. 4.



A diagram of the spectrum of light with three curves representing the degree to which the various wave-lengths produce heat, light, and chemical changes. The shaded area indicates the wave-lengths that are present in the average bacterial light. It can be noticed that these rays approach the maximum of visibility and avoid that part of the spectrum that provides heat.

least amount of energy, expended a maximum of visibility to the human retina is produced. Also, it is probable that the eyes of other creatures have more or less the same kind of sensitivity as ours, which would make this light most easily seen by them, too.

Nature seldom fails to show by the characters of her products what reason there is for their existence, and in this case it can hardly be that the light of bacteria is an aimless by-product. It has been fitted by its course of evolution to be seen, but just by what creatures or for what benefit to the bacteria cannot be said.

The considerable amount of chemical power exerted by the rays coming from the bacteria is indicated by the portion of the chemical curve which is intersected by the shaded area representing the bacterial light. This is also evidenced by the fact that photographs can be taken of the luminous colonies and of objects

that these colonies are used to illuminate, as the skull which is shown in Fig. 3, after being photographed by Molisch in the dark room by the light of two gelatin cultures of bacteria.

That some of the rays of the bacterial light are heat rays has been proved by physical instruments only in a few cases. One of the first questions asked by the most superficial observer is always, "Is this light warm or hot?" One cannot detect any warmth by the hand or lip. Nor will the more delicate thermometer show any heat if placed in contact with the shining bacteria. Hulme attempted to detect heat, but his results were negative. To this date, therefore, we cannot positively say that any heat is produced, but, knowing that in the insect a very minute quantity has been proved to be present, and believing that the light in both cases is produced in the same way, we feel some certainty that a very small quantity is produced as an unavoidable by-product in the bacteria during their luminous condition.

It is well known that among the different luminous forms of life there are mechanically two important ways in which the luminous material (luciferine) is used to produce the light. One is its use outside of the cell that produced it (extracellular theory), and the other is its use, *in situ*, in the secreting cell or tissue (intra-cellular theory).

The bacteria are such minute organisms that this rather important question cannot be readily determined. The light from a single individual is so small in quantity that it is not visible under the higher power of the microscope.

Ludwig and Dubois both believed that the light was produced outside of the bacterial cell by luciferine that was secreted inside the cell and passed outside through the pellicle or skin that surrounds each bacterium. They reasoned by analogy, knowing that the bacteria often work in this way in making and using various pigments, toxins, enzymes, etc.

Most observers, however, who have attacked the problem seriously agree that this view is not correct, and that the luciferine is actually oxidized and the light produced inside of the cell. Some of their reasons are as follows:

Lehmann and Sirotinin both filtered actively glowing bacteria through a porcelain filter and found that none of the bacteria free fluid that went through was luminous.

E. Newton Harvey centrifuged bacteria in a fluid medium and

found that the light was confined to the solid mass of organisms. This evidence is much like the preceding.

Further, strong but indirect evidence is to be considered in the fact that, when the bacteria are killed by sudden heat, grinding, or pressure, or are ruptured by the osmotic conditions when pure distilled water is poured on them, the light is suddenly extinguished. This points strongly to some mechanical arrangement of the substances that is necessary for light production, and points

FIG. 5.

Some luminous bacteria (*Pseudomonas*) drawn from a methylene blue preparation on the slide. The inclusions may be vacuoles of the light-producing substance. (Drawn by Miss E. Grace White.)

particularly to the need of an intact pellicle as a condition of luminescence.

By some it has been thought that a segregation of the luciferine could be observed in parts of the bacterial body after fixing and staining on the slide. Vacuoles have been observed by the writer as well as by others which seemed to be present in actively luminous cultures and absent in those broods that were not producing light at the time, although healthy and in condition of active multiplication (see Fig. 5).

What, then, is the material that is secreted by the bacterial organisms that is burned in the presence of oxygen and in burning releases its stored energy in the form of 98 to 99 per cent. of light? The work of E. N. Harvey shows us some progress in solving this question.

It shows that the material is not a living one, because we can kill the bacteria by drying, and the ability to glow is left when moisture and oxygen are present again.

Dried bacteria can be extracted with ether (boiling) and toluol, and when dried from these solvents and moistened with oxygen-bearing water they once more glow. Therefore, the matter (luciferine) is not a fat and is not destroyed by ether or toluol.

If we destroy the integrity of the cell by grinding when dried or by cytolizing with distilled water, we destroy the power to illuminate. Evidently there is some structure in the cell that is necessary for the use of the luciferine. Possibly such structure has to do with the separation of two or more substances that are kept separate but brought together to produce light. Further work in this chemical line can probably be better done in some of the more highly specialized light-producing forms to be treated in a succeeding chapter.

(To be continued.)

The Electric Arc in the Foundry. R. KINKEAD. (*Proceedings of the American Foundrymen's Association,* September 28 to October 1, 1915.)—The application of the electric arc in the foundry to what is generally known as the arc-welding process can be employed for reclaiming steel and malleable castings which otherwise would be scrapped, due to defects originating in the casting process, such as sand spots and shrinkage cracks; for the improvement of the quality of steel and malleable castings which would not be scrapped; for the manufacture of steel castings which, owing to their shape, will always crack upon cooling, and for the cutting of gates and shrinkheads.

The effect upon the metal of the heat produced by the arc is the same as that produced by any other method. There is, further, no greater danger of overheating the metal than by any other method used in the foundry. The arc-welder is a motor-generator set which takes power from the supply lines at whatever voltage the power is purchased, either alternating or direct, and delivers direct current at about 75 volts. Resistance ballast is employed to bring the voltage down to 50 or 25, according to whether a carbon or metal electrode is used.

Pilot Flame Ignition of Incandescent Gas Lamps. C. W. JORDAN. (*Transactions of the Illuminating Engineering Society*, September 20–23, 1915.)—The subject of pilot flame ignition of incandescent gas lamps may appear to many to be rather a minor or unimportant detail of the broad general subject of gas lighting, and yet on analysis it will be found to be extremely vital for the successful operation of lamps in practice. Convenience in gas lighting has become a necessity, and many devices have been perfected for securing automatic ignition, in some cases controlled from distant points. Despite the ingenuity shown in the design and mechanical devices for securing automatic ignition, they have not met the practical requirement of service.

Other devices, such as pyrophoric ignition, self-lighting mantles, etc., are not extensively used because of the ease with which the mechanical parts get out of order or on account of the short life of the active material. The simple pilot by-pass and gas-cock actuated by pulling a chain meet the demand for convenience, economy, and service in a most satisfactory manner.

Consumers are often badly misinformed or entirely ignorant of the consumption of gas by pilots. The consumption of a one-burner indoor pilot is in the neighborhood of 1000 cubic feet per year. The consumption by pilots varies from 8 to 20 per cent. of the total consumption with the usual type of burner.

Oerlikon Electric Induction Tire Heater. ANON. (*La Revue Electrique*, vol. xxiii, No. 276, June 18, 1915 (issued Sepember 3, 1915).)—In heating locomotive tires and other like parts for shrinkage operations it has been the practice, in order to avoid the soot and cinders of a coal furnace, to employ the gas blast. While answering the purpose satisfactorily, that type of heater has the disadvantage of requiring a separate burner for each size of tire, and the attendant complexities of the air-blast installation and piping.

With the object of producing a device adapted to pieces of different dimensions and free of special installation for its operation, the Oerlikon Works have recently introduced a special transformer for heating operations of this type.

In its essential features it consists of two cylindrical cores of a U-magnet, with their permanently-attached yoke supported on a suitable truck. Surmounting the cores is a pole-piece arranged to be swung aside about one or the other of the cores and capable of being firmly clamped in magnetic contact with the cores when in use. A primary coil over one of the cores only is employed. In operation the tire surrounds one or the other of the cores. When sufficiently heated the piece is removed by swinging aside the pole-piece. Straight bars may also be heated by arranging them in proximity to the core, with their ends connected with copper cable to form a closed inductive circuit.

RECENT RESEARCHES IN ELECTRICITY AT THE BUREAU OF STANDARDS.*

BY

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BEFORE referring to the recent researches carried out in the electrical division of the Bureau of Standards, it will be desirable to say something of the electrical laboratories and their material equipment, and the different kinds of work included in the electrical division.

The new electrical laboratory building is a substantial structure of brick and stone, occupying a ground area of 190 by about 60 feet, and five stories in height. It is constructed as economically as possible consistent with good materials and workmanship, and proper adaptation to its uses, no attempt being made to make it either ornate or monumental. It cost, including plumbing, heating, lighting, and elevator, but not the laboratory piping and wiring nor furniture, $200,000. A similar sum will be spent for a building of about the same size for the chemical division, plans for which are now being prepared. The three principal buildings which the Bureau had before, together with two smaller ones, cost, without furniture or instrumental equipment, about $600,000. The entire group of buildings, therefore, including the chemical building shortly to be begun, cost about one million dollars, and their equipment represents as much more.

The basement plan of the electrical building is very similar to the other floors. There is a main central corridor, with rooms on either side and a group of rooms at either end. At the north end are the dynamo room and workshop, the former containing a number of motor-generator sets, nearly all built to order, for supplying current for experimental purposes, in addition to the alternating and direct current supplied from the plant in another building. A large number of storage batteries furnish steady cur-

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section of the American Institute of Electrical Engineers held Thursday, February 11, 1915.

rent for experimental use, and a small separate building nearby contains transformers for high-voltage work.

Some of the laboratory rooms in the basement are for the rougher kinds of experimental work, and some are for the most refined work, where steady supports on a bed of sand resting on the earth below the floor level give freedom from vibration. The machines in the dynamo room are all carefully balanced and are carried on a large block of concrete, which also rests on a bed of dry sand, out of contact with the floor or walls of the building.

FIG. 1.

Electrical Laboratory—Bureau of Standards.

This reduces vibration to a minimum, but some of the most delicate apparatus still detect some vibration, and hence additional precautions are taken with such instruments.

The first floor is devoted entirely to laboratories for experimental work in electrical and magnetic measurements; the second floor contains more laboratories and also some offices and a conference room; the third floor is devoted to work in photometry and illuminating engineering and the work in radio-active measurements; the fourth floor provides for the work in radio-commu-

nication and gas engineering, and contains the main lecture room of the Bureau, seating 300. The attic floor is subdivided into storage rooms and provides one or more rooms for each separate section of the work. The heating is by hot and tempered air, regulated by thermostats, the heating ducts and wiring and piping for the entire building being distributed through a subbasement corridor to four vertical shafts that supply the rooms on each floor. Below this is a vault, where the temperature remains nearly steady throughout the year, at substantially the earth temperature, 30 feet below the surface of the ground.

The work of the electrical division is subdivided into eleven separate sections, as shown below, some of the sections being further subdivided, these subdivisions, however, not being indicated. The first five of these sections were established early in the history of the Bureau. The remaining ones are relatively new.

Section 1.—Standards of resistance and electromotive force, and precision apparatus and methods for measurements of resistance and electromotive force.

This work includes the preparation of fundamental standards of resistance (mercury in glass tubes according to the specifications for the international ohm); the maintenance of the fundamental unit by means of sealed wire standards; the derivation of all the other denominations from the one-ohm standards; the study and improvement of methods of measurement; the design of new apparatus for use in such measurements; the testing and certification of standards of resistance and of other precision apparatus; the investigation and improvement of standard cells for standards of electromotive force; and the testing and certification of such cells.

Section 2.—Standards of inductance and capacity and of radioactivity; absolute measurements of current, resistance, and other electrical quantities; and the investigation of the silver voltameter as the fundamental standard for the international ampère.

In this section a large amount of work has been done on the methods of measurement of inductance and capacity; the improvement of inductance and capacity standards and the testing of such standards; measurement of the capacity and inductance of instruments; the absolute measurement of current by means of current balances; the determination of the ratio of the electrostatic and electromagnetic units; the investigation of the silver voltameter

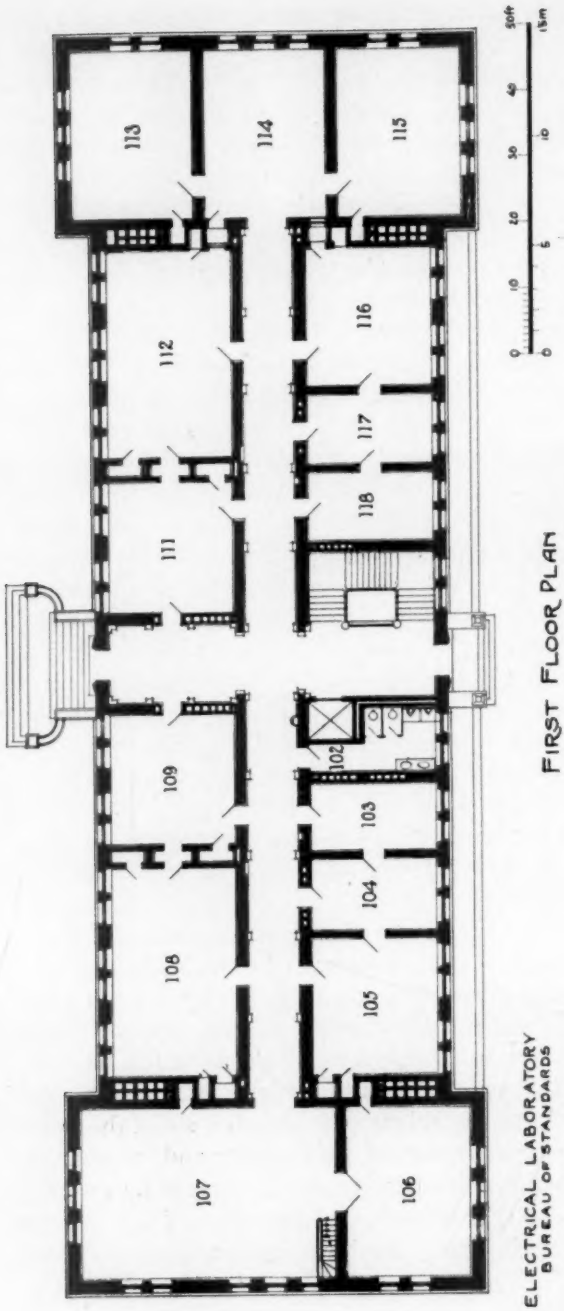

FIG. 2.

Electrical Laboratory, First floor plan.

with a view of obtaining the highest degree of reproducibility, and of obtaining information on which to base international specifications; the calculation of inductances from their dimensions; and the investigation of radio-active measurements and the testing of radium and other radio-active substances.

Section 3.—Electrical measuring instruments, including ammeters, voltmeters, wattmeters, watthour meters, phase and frequency meters, current and potential transformers, batteries and other instruments and apparatus used especially in commercial and engineering work.

This work includes the theory and practice of a large part of the measurements and testing of electrical engineering, as opposed to the more precise measurements with standards and the precision apparatus included in Sections 1 and 2. The work, however, involves a thorough knowledge of the theory of instruments and measurements, and many refinements in the conditions of the tests. Some of the work is of a research character even when it is nominally a test, for many of the tests are new, and frequently require the development of the methods and sometimes even of the instruments employed.

Section 4.—Magnetic measurements, including the development of standards and methods of measurement; the testing and improvement of instruments for magnetic measurements; the testing of samples of magnetic materials for permeability and hysteresis; and the investigation of the relation between the magnetic and the mechanical properties of magnetic substances.

The work done in this section has covered a wide range and exerted a great influence on the methods and instruments used in this country in the commercial testing of iron and steel. The accurate measurement of magnetic quantities is beset with peculiar difficulties, one of the chief being the more or less uncertain variation of the quantity being measured. The dependence of the magnetic properties of a substance upon its mechanical properties and the heat treatment it has received has long been studied, but much remains to be learned, and the Bureau has been working on the subject for some time.

Section 5.—Photometry and illuminating engineering, including the methods and instruments of photometric measurements; the testing of photometric standards (both flame standards and electric lamps used as standards); the investigation of light

sources, especially those used as primary or secondary standards; the study and testing of lighting fixtures and accessories; and the inspection and testing of electric lamps for the government.

This work covers a very broad field, from the research concerned with the development and maintenance of standards to the inspection and life-testing of lamps to determine their quality as light sources, and whether they conform to standard specifications. By supplying standardized electric lamps to the manufacturers and testing departments of cities, commissions, and operating companies, and testing and certifying gas-flame standards for gas companies and inspection departments, the Bureau has brought about a uniformity in candle-power measurements which did not exist before.

Section 6.—Radio-communication or wireless telegraphy, including the investigation of instruments and methods of measurement; the design and improvement of measuring instruments; the testing of instruments used for the measurement of wave frequencies and logarithmic decrement; the testing of high-frequency ammeters and other high-frequency instruments; the design of signalling apparatus for various branches of the Federal Government; and coöperation with the Bureau of Navigation in the administration of the Federal laws regulating the use of wireless apparatus.

This work includes many of the most important aspects of signalling by the use of electromagnetic waves of high frequency, as well as the investigation and testing of instruments for quantitative measurements. The work at the Bureau is relatively new, and is not as well established as most of the work previously mentioned, but enough has been done to show the advantage and desirability of greatly extending it.

Section 7.—Electrolysis mitigation and other problems connected with electric railway operation. This and the next four sections pertain to public utility service, and are carried on mainly by means of special appropriations.

Electrolysis mitigation is one of the most urgent problems in connection with electric railway operation, and for this reason it was taken up first. This work includes laboratory investigations, field studies and surveys, and special investigations as to methods of keeping street railway current out of the pipes, cable sheaths, and underground structures which are injured or destroyed by

electrolytic corrosion. Other problems which remain to be taken up in this field have to do with (1) the quality and adequacy of the service, (2) the efficiency and cost of service, (3) the safety of service and methods of reducing accidents to employees and the public, and (4) studies of regulation, inspection, and administration.

Section 8.—Standards for electric lighting and power service, including a study of what constitutes safe and adequate service under different conditions, and what requirements can be made of different classes of utility companies regarding the uniformity of voltage, continuity of service, accuracy of meters, attention to complaints, etc.; and also a study of various problems of street lighting. The investigations are of a different character from those in the preceding sections, but are nevertheless important and require a scientific and unbiased attitude of mind on the part of the investigators.

In this work the coöperation of the state commissions, municipal inspectors, operating companies, and committees of engineering societies has been obtained, and the work has the indorsement both of the commissions and other representatives of the public and of the utility companies.

Section 9.—Standards for safe operation of the electrical utilities, including the formulation of rules applying to the construction of electric lines (overhead and underground) and the installation of electrical apparatus and machinery.

This work includes the preparation of a National Electrical Safety Code, which is having the coöperation of all the electrical utility companies, including the light and power, street railway, telephone and telegraph companies, and also the steam railway companies, which are concerned partly because they use electric signalling systems and partly because the lines of other companies cross their tracks and signal lines so frequently. The work includes also the questions of inspection of electric power stations, transmission and distribution lines, and the apparatus and machinery employed in the industrial uses of electricity. The work will also include the periodical revision of the Safety Code after its issuance, and coöperation with the National Fire Protection Association in the revision of the Fire Code.

Section 10.—Standards for gas service and safety, including the study of the elements of good service; the legal requirements

that can fairly be made of gas companies; the inspection and testing methods to be used by state commissions and municipal officials; and a national gas safety code for the use of the manufacturers, distributers, and users of gas.

This work has been in progress for six years, and has progressed further, so far as standards for service are concerned, than the corresponding work in electric service. The Safety Code is just being taken up.

A large amount of research and testing has been carried out in connection with this work, in which the chemical and heat divisions have shared. The methods of testing gas for heating value, candlepower, chemical purity, and pressure are fully treated in various publications, and some state commissions and city officials have been assisted in formulating rules for local use.

Section 11.—Standards for telephone service, including the specification of what is good performance by transmitters, receivers, and other parts of telephone equipment and of the system as a whole, together with studies of the regulation of telephone service by public authority.

This work is just being taken up, and so far nothing has been prepared for publication. It is one of the most important fields of public utility service, and offers an opportunity for scientific and engineering work of great importance.

Having stated the various lines of work carried on in each of the separate sections of the electrical division, we may now consider some of the particular investigations recently completed or still in progress. Examples will be given under each section, but time will not permit mentioning all.

THE MERCURY OHM.

The unit of electric resistance is defined by international agreement as the resistance of a column of mercury in a glass tube kept at the temperature of melting ice, the length of the column being 106.3 cm. and the mass such that the cross-section is about 1 sq. mm. The difficulty of preparing such standards of resistance is so great that several glass tubes are prepared with suitable terminals and then filled repeatedly, the electric resistance being taken after each filling. The greatest care is taken in measurements of the length of the glass tubes, in filling so as to exclude the slightest film of air between the mercury and glass, in securing uniform

temperature throughout (accurately at zero) and in getting the resistance in terms of wire standards with the highest possible precision. Every possible source of error must be avoided in order that the mean of several series of determinations shall be correct within two- or three-thousandths of one per cent. when all sources of error are included. Such resistance standards are set up only at standardizing laboratories in a few countries of the world, and by agreement among these laboratories the international ohm is taken as the mean of the values found. A paper describing the work at the Bureau on this subject has recently been completed.

WESTON NORMAL CELLS.

The standard of electromotive force adopted by international agreement at the London Electrical Congress of 1908 is the Weston normal cell. Specifications for its preparation call for the use of pure materials, but when measurements are made to the millionth of a volt it is found that appreciable differences occur in different cells, all of which are made from equally pure materials. Investigations extending over several years have shown that these small differences are chiefly attributable to variations in one of the chemical substances; namely, the mercurous sulphate. This substance may be prepared with sufficient purity either chemically or electrochemically, but the results obtained for the electromotive force of the cell are different when materials are used which have been prepared in slightly different ways, and they also differ appreciably with different lots prepared in the same way if the details of the preparation have been slightly varied. For example, it is known that the electromotive force varies appreciably between cells containing electrolytic mercurous sulphate prepared by the use of direct current from the values when electrolytic mercurous sulphate is used which has been prepared by means of alternating current. Further, it has been found that mercurous sulphate prepared electrolytically by means of alternating current gives cells of very constant electromotive force, but different samples prepared in somewhat different ways do not quite agree. The study of these differences has been actively in progress for some time at the Bureau. It has been learned that the electromotive force of the cell varies according to the strength of the current that has been used in preparing the electrolytic mercurous sulphate, and

also according to the temperature of the solution and its concentration and the method of its stirring, the explanation being that the size of crystals of mercurous sulphate is affected by variations in these particulars of treatment. This investigation illustrates how much additional work is involved in extending the desired accuracy by another decimal place. If we desired only reproducibility of the standard cells to the hundredth part of one per cent., it would be very easy to prepare the cells. A reproducibility of a thousandth of one per cent. is much more difficult and requires enormously greater precautions and labor. To try to get reproducibility to a few millionths of a volt is still more difficult. However, the endeavor to secure the highest possible reproducibility leads to the discovery of hitherto unsuspected sources of differences and gives a more complete knowledge of the theory of the cell. We believe that the result of this investigation will enable official specifications to be drawn which will be so much more complete than those heretofore used that the Weston cell as a standard of electromotive force will be greatly improved.

The unsaturated Weston cell is used in ordinary electrical measurements instead of the standard form which is saturated, the reason being that the former has a smaller temperature coefficient. The Bureau is investigating this type of cell also with the hope of being able to prepare cells that will be more constant and in better agreement with one another, and therefore more useful for precision measurements.

GALVANOMETERS.

Another investigation which has been in progress for several years, and which has yielded very valuable results, relates to sensitive moving-coil galvanometers. In comparing resistance standards with the highest possible accuracy, and without using enough current to change their temperature appreciably, it is necessary to have galvanometers of extraordinary sensitivity. Moving-coil galvanometers of suitable characteristics are so much more convenient in use than moving-needle galvanometers that they are almost always used in this work. The need of galvanometers of maximum sensitivity has led to a thorough study of the theory and design of such instruments, and a number have been built in the instrument shop of the Bureau which have been of higher sensitivity than any which we possessed before, notwithstanding

that we had the most sensitive instruments to be purchased anywhere in the world. A paper on the theory and design of such galvanometers has been prepared. This paper discusses the mathematical relations between the operating constants of the galvanometer and the factors entering into its construction, such as the magnetic field and the shape, size, and kind of material of its parts. Directions are given for the construction of galvanometers for various special uses.

ALTERNATING-CURRENT GALVANOMETERS, ETC.

Alternating-current bridges are much used in electrical measurements, and it is necessary to have some detector of high sensitivity responding to alternating current of the frequency used in the bridge. Sometimes a telephone is used, sometimes a tuned galvanometer (also called a vibration galvanometer), and sometimes an electrodynamometer having a separately-excited electromagnetic field. For alternating currents of low frequencies the telephone is not sensitive and the vibration galvanometer is generally used. The latter, however, is not as sensitive as is desirable in some kinds of work. A careful study of the problem, making use of the experience gained in the construction and use of sensitive galvanometers for direct current, led to the development of an alternating-current galvanometer of extremely high sensitivity, and a paper describing the work has been prepared for publication. These galvanometers have been made as sensitive as the best direct-current galvanometers, and while, in some respects, not as convenient to use as the usual form of tuned galvanometer, they are much more sensitive and will be very useful for certain kinds of work.

An improvement in the accurate measurement of temperature has been made possible by a new potentiometer designed and constructed recently. The settings of the potentiometer are varied by moving a high-resistance shunt from one set of coils to another. Thermal electromotive forces generated at the sliding switches do not affect the measuring circuit.

THE SILVER VOLTAMETER.

The International Electrical Congress at London in 1908 adopted the international ampère as a second fundamental electrical unit (the first being the international ohm), and defined it

as a current which will deposit 0.00111800 gramme of silver per second from an aqueous solution of silver nitrate under certain conditions, some of which were not specified. The silver voltameter had been subjected to many investigations during the thirty years preceding the London Congress, and many papers have been published in various countries concerning it. However, the differences in the results obtained, and in the opinions of different investigators as to the causes of these differences, were such that detailed specifications could not be agreed upon at the time, and they were left to be developed later. In 1910, an International Committee assembled in Washington, at the Bureau of Standards, for the purpose of investigating the instrument further. This committee represented the national standardizing institutions of Germany, France, and England, as well as the Bureau of Standards. As a result of two months' continuous work on the subject in Washington, a report was prepared which gave considerable further information concerning the use of this important electrical standard. However, there still remained some obscure causes of variation, and the Bureau of Standards has continued the investigation up to the present time, and has published several papers giving the results of the work as it progressed. During the current year further investigations are being made, some of which are in coöperation with Professor Hulett, of Princeton, and others of which are for the purpose of checking results found at Harvard. The outstanding sources of differences are so small that measurements must be made to within about a thousandth of one per cent. It is hoped that in the near future complete official specifications may be prepared which will be adopted internationally.

INDUCTANCE AND CAPACITY MEASUREMENTS.

The resistance and inductance of bimetallic wires is another subject which has been under investigation at the Bureau. Wires made up of a steel core, with an outer copper sheath, are used in electric power transmission and in telephone work. The resistance and inductance of such wires to alternating current vary with the frequency of the current, and it was of considerable importance to determine the law of such variations. The investigation resulted in the derivation of formulas for calculating the

variation of resistance and inductance, and the results of the calculations were checked by measuring them experimentally. The magnetization of the steel core by means of the current flowing through it is circular, and a study was made of the relation between the circular and longitudinal permeability of wires.

The Bureau has made a very thorough investigation of the measurement of electric capacity, and of various types of condensers with respect to the relation between their capacity and the energy expended upon them when submitted to definite alternating electromotive forces. Important improvements in the quality of mica and paper condensers have been made as a result of this investigation. Recently a set of standard air condensers has been built which will be of great use in research work and precision testing, since they are more constant and of much larger capacity than the condensers previously used for the purpose. Special types of air condensers have been designed and used in connection with measurements in radio-telegraphy, the shape of the plates being such as to facilitate the direct reading of decrements.

RADIUM.

One of the most recent lines of work taken up by the Bureau is the investigation and measurement of radium and radio-active substances, including radium emanation, radium minerals, and radio-active waters. The Bureau has a standard specimen of radium which is standardized in terms of the international standard preserved at Paris, and makes a large number of measurements of sealed radium specimens to determine by means of their gamma radiation the quantity of radium contained. Various radium products and preparations for therapeutic use are also submitted to the Bureau for test. It is important that physicians using radium shall know definitely the quantity contained in their specimens in order to be able to correlate the results obtained with the strength of radiation employed. Also, when radium sells at the rate of three and one-half million dollars an ounce, it is important that the purchaser of a specimen should know how much radium is actually contained in the brown powder, some of which may be sand which without measurement may be passed as radium. It is also important to subject so-called therapeutic preparations of radium and radium salts to a test of actual measurements in

order to discourage fakes and frauds. The Bureau has made a very careful study of methods of measurement, and has a considerable instrumental equipment for such measurements.

ELECTRICAL MEASURING INSTRUMENTS.

Several investigations on the testing of current and voltage transformers have recently been made and the results published; other papers in connection with the testing of electrical measuring instruments have also been published. A thorough study of such instruments has been made in connection with the testing work, and recently a second edition of our circular, which is really a treatise on that subject, has been prepared for publication. The Bureau's facilities for the testing of such instruments are very complete. Alternating current of a wide range of frequencies and adjustable wave-form is available for such tests, being delivered from machines which can be run at constant speed, giving a remarkably constant frequency of alternation in the current. Instruments may be maintained at constant temperature which may be regulated at any point between freezing and such temperatures as prevail in engine-rooms, so that change of frequency, or change of wave-form, or change of load, or the effect of a strong magnetic field upon it, or any one of many variations of conditions which may arise in practice, can be separately determined. Inasmuch as all makes of instruments are submitted either by the manufacturers or their customers, and in many cases extended investigations are made, the Bureau is in possession of a very large amount of detailed information on the performance of various kinds of electrical measuring instruments which has never been published. Bureau Circular No. 20 is a discussion of such instruments, based upon the experience of the Bureau for fourteen years, since its establishment, together with criticisms and suggestions received from a number of the most experienced manufacturers and engineers in the country. This is one of the most carefully prepared and useful publications of the Bureau.

In the testing of instruments used in high-voltage and heavy current measurements the Bureau is well equipped. A special building contains transformers of 5000, 25,000, and 100,000 volts, which furnish current for the calibration of high-voltage measuring apparatus and for testing and investigation. A battery capable

of furnishing 5000 ampères at steady voltage is used in the testing of heavy current instruments, and permits current-carrying standards to be certified and their temperature coefficient studied.

MAGNETIC INVESTIGATIONS.

In the magnetic work the Bureau has made very thorough investigations of methods of measuring permeability and hysteresis loss, including apparatus for precision measurements and also the more convenient and rapid apparatus for commercial use. A great deal of attention has been given to the preparation of standards, and this has involved a thorough study of the methods of bringing specimens of iron or steel into a standard initial condition so that when magnetized by a certain procedure the result of magnetization will always be the same. This proved to be one of the most important as well as one of the most difficult conditions to meet in the preparation and use of standards. Comparisons have been made with the magnetic standards of the standardizing laboratories of Germany and England, so that for the first time in the history of magnetic measurements we are assured of international uniformity in numerical expression of the results of measurement.

Recently a thorough investigation of a particular type of permeameter has been completed, an instrument which has been extensively used for commercial testing, but which is capable of giving results differing considerably according to the conditions of the test. This investigation will lead to improvements in the results obtained by such instruments.

Another recent investigation in magnetism at the Bureau is concerned with the temperature coefficient of permeability. Heretofore temperature has usually been neglected in the measurement of permeability, but it has been shown by this recent investigation that the temperature coefficient may be as great as one-third of one per cent. per degree, and, inasmuch as the temperature of the specimen is subject to variation not only from varying room temperature but also from the current used in magnetizing the specimen, the uncertainty in the temperature, if it is not carefully measured, may be a good many degrees, and the effects upon the result may be several per cent.

Another investigation of considerable practical importance has been a study of the core loss in specimens of iron at very high inductions, under which conditions the measurements are rela-

tively difficult. As a result of this investigation it is now possible to obtain satisfactory results when the limits of the magnetic induction are extended from 10,000 to 15,000 units.

Still another investigation, upon which a large amount of work has been done, is the study of the relation between the magnetic and the mechanical properties of magnetic substances, and the practical application of this work to the detection of flaws in steel rails or other magnetic materials. Apparatus has been developed by means of which photographic records show the location of such hidden flaws under some circumstances, and one question that has been considered is whether it will be possible to utilize such a method in practice as a check upon the quality of steel rails. However, the results so far obtained do not show that this is commercially feasible, although further work may make it seem more practicable. More information, however, on the subject of the relation of the magnetic and mechanical properties of materials cannot fail to be of great scientific interest, and without doubt will prove of practical value also.

PHOTOMETRIC INVESTIGATIONS.

As photometric standards for use in testing the quality of gas or the illuminating power of light sources burning gas, flame standards are usually employed. The candle-power of such flame standards varies with the atmospheric conditions surrounding them. The lamp itself is, of course, not a standard, but a lamp made according to certain specifications, burning a fuel which conforms to other specifications, in an atmosphere which also conforms to definite specifications, and, handled in a certain definite way, will give the normal candle-power, and the entire combination constitutes the standard. Variations in atmospheric humidity and variations in atmospheric density or in the composition of the atmosphere all affect the candle-power of the flame. The Bureau has made very extended studies of the effect of atmospheric moisture upon the candle-power of flames, and has made it unnecessary to determine the effect of vitiation of the atmosphere from the products of combustion by securing perfect ventilation in the lamps under test. However, the effect of varying atmospheric density due to ordinary fluctuations of the barometer, or due to varying altitudes above sea level, had never been measured with sufficient accuracy until the recent work at the Bureau. It

was first proposed to make several series of measurements upon flame standards at several stations located at different altitudes above the sea level from 3000 to 10,000 feet, and to calculate from these measurements the rate of change of candle-power with the change in barometric pressure. It was, however, found possible to build an apparatus in which these flame standards could be burned in the laboratory in such a way that the air could be circulated rapidly through the apparatus at any desired constant pressure (within rather wide limits) and the candle-power measured as accurately as when the flame is burning in an open room. A long series of measurements of this kind on various light sources has furnished accurate determinations of the rate of change of the light with the atmospheric pressure, which is found to be different for each different light source; and with gas lamps it varies for the same gas with different types of burners. It is now possible for the first time to certify not only the normal candle-power of a pentane lamp used as a standard, as heretofore, but also to state what its candle-power will be at any particular altitude above sea level. The effect of atmospheric humidity has also been redetermined in this apparatus, the results agreeing very closely with those previously found.

Another investigation which has been in progress in the Bureau for some time, which is of very great practical importance, is the problem of determining the ratio of the candle-power of light sources of different colors. A photometer is an instrument used to compare the intensity of different light sources, and accurate and consistent results may be obtained when the lights have the same color, but when the colors differ appreciably it is difficult to say when two surfaces are illuminated to the same intensity. Accordingly, different observers will differ as to the value to be assigned to a given light source in terms of a standard of a different color. These differences are in part accidental and in part systematic. The accidental errors may be largely eliminated by having observers take a large number of observations. The systematic readings depend in part upon the variation in the eyes of different observers. The standardization work that the Bureau has done upon lights of different colors has been based upon results of a considerable number of observations, and we have had very satisfactory agreements in making intercomparisons with the National Physical Laboratory of England upon the

candle-power of certain tungsten lamps rated in terms of carbon lamps burning at 4 watts per candle. Nevertheless, the work is not yet upon an entirely satisfactory basis, and the investigation is being continued.[1]

One of the important results of this work is the discovery that tungsten lamps of different makes and different types have very closely the same characteristic curves which connect candle-power with voltage, so that it is possible for a given lamp to be rated for candle-power at several different voltages, which correspond to several different colors, and one lamp may thus serve the place of a series, and furnish means for testing lights of appreciably different color without a color difference in the photometer. The characteristic curves are expressible by a simple mathematical equation.

Another investigation of interest and importance in connection with modern lamps has had to do with the measurement of the candle-power of gas-filled tungsten lamps. It has been found that the candle-power and efficiency of such lamps vary when they are rotated from the value they possess when stationary. Partly for this reason and partly because of their very white color and large candle-power units, the photometry of such lamps has been especially difficult. For several years the Bureau has prepared photometric standards by seasoning incandescent lamps and rating them as to efficiency and candle-power, so that the manufacturers and testing laboratories of the country are supplied with standards in very close agreement. These electrical candle-power standards are so much more uniform and reliable than any so-called primary standards as yet developed that they are, in effect, the primary standards of the country. Flame standards built according to specifications vary so much that it is necessary for each to be separately standardized in terms of the more constant electrical standards.

RADIO-COMMUNICATION.

The work of the Bureau on radio-communication, or wireless telegraphy, as it is more commonly called, dates from the time when a Federal law was passed requiring passenger ships to be

[1] A more complete investigation of this subject has been undertaken since the date of this lecture, and important results already obtained were recently communicated to the Illuminating Engineering Society.

equipped for radio-communication and to have an auxiliary source of power that will be sufficient for signalling 100 miles when the main source of power is disabled, and also requiring that the wave-lengths employed in such signalling shall be not more than 600 metres, and that the damping of the electromagnetic waves sent out should be not greater than corresponding to a logarithmic decrement of 0.2. The administration of this law rests with the Bureau of Navigation, but the Bureau of Standards serves as its scientific adviser, and designs and tests apparatus for its inspection service. The instruments used by the inspectors for measuring wave-lengths and logarithmic decrements were designed at the Bureau and built according to our specifications, and have been calibrated, and from time to time recalibrated, at the Bureau. We have also designed and superintended the construction of complete radio equipments for several ships, both of the Bureau of Navigation and of the Bureau of Lighthouses.

An investigation of radio interference was made by the Bureau on the Pacific coast in answer to complaints that a commercial station was interfering with the use of wireless by the Navy Department.

Problems in connection with wireless signalling are under investigation at the Bureau with the hope of increasing the usefulness of this important means of communication in fogs at sea. Other investigations have to do with the high-frequency testing of inductance coils, condensers, ammeters, and other instruments used in the transmission and receiving of wireless messages.

PUBLIC UTILITY INVESTIGATIONS.

The research work that has been carried on in connection with the various lines of public utility work has been partly in the laboratory and partly in the field, supplemented by extensive correspondence. Methods have been investigated for testing gas for candle-power, heating value, chemical purity, etc., and for testing electrical instruments used in measuring the service rendered by electric companies. A large number of investigations have been made in connection with electrolysis mitigation upon soil resistance, the corrosion of pipes buried in the ground, the effectiveness of waterproofing and insulating compounds in actual use, the different kinds of bonding employed

in electric railways for securing an electrical connection between rails, the electrical resistance of different kinds of roadbeds, the relative corrosion due to alternating currents and periodically reversed direct currents as compared with continuous direct currents on underground structures, and other similar questions. In field studies, inspections have been made and electrolysis surveys conducted in a number of cities, and reports prepared showing how conditions could be improved, what the effect would be upon operation, and what the net cost of securing freedom from electrolysis damage would be. By correspondence, information has been collected with regard to practice of utility companies in different lines of work, the requirements and inspections made by cities and state commissions, and other information gathered that would be useful in the preparation of a complete discussion of the subject of standards for gas or electric service.

The work in connection with telephone service is only just being taken up.

Another important line of study has been in connection with the life hazard in electrical practice, in the preparation of a National Electrical Safety Code. This work has been in progress for more than a year, and a very large amount of information has been gathered on the subject of safe practice in the production, distribution, and utilization of electricity. Statistics with regard to accidents are collected, coroners' reports upon fatal accidents studied, causes of serious and fatal accidents determined so far as possible from reports to state commissions or by special correspondence with the companies concerned, and such results have all been utilized in the formulation of rules for safe construction and operation. Although this investigation does not involve much experimental work, it is nevertheless a very important example of really scientific research work. The ultimate aim of deriving from it a truly National Safety Code that can be adopted by the public service and industrial commissions in the various states and by cities, as generally as the Underwriters' Fire Code is adopted, is of great interest and importance.

The preparation of a National Gas Safety Code has also been undertaken. This will not only cover the ground of the Electrical Safety Code, but will also include the fire-hazard side of the question. The Gas Safety Code will be concerned with the manufacture, distribution, and utilization of gas and will be divided into

five parts. The first will have to do with the manufacture of gas, the second with its distribution, the third with the design and construction of gas appliances, the fourth with the piping of buildings and the installation of appliances, and the fifth with the use of gas and the care of appliances. This investigation involves the collection of information from the industry, the study of rules formulated by companies and by municipal inspection departments, and the experimental study of gas appliances, in coöperation with manufacturing and operating companies.

Another problem of engineering interest and importance which the Bureau has been studying recently is that of the service rendered by electric light and power companies, and the specifications for good service that can be set up by public service commissions or cities that have the authority to regulate such service. The question as to what is safe and adequate service under certain conditions is one that requires very careful study and familiarity with practice in many places. The requirements that can be met as to steadiness of voltage and continuity of service offered under different conditions can be fixed only after careful consideration of best current practice under defined conditions. Ordinances have been prepared for cities of different sizes and for plants operating under different conditions, and rules suitable for adoption by state commissions have been formulated. This work has been done in close coöperation with the public utility companies and the state commissions, and is an example of a different kind of investigation from most of those already cited. It is, however, of just as great practical importance and public interest.

This brief survey of the current research work of the electrical division of the Bureau of Standards indicates that it covers a wide range of subjects, so wide indeed that a much larger force is needed to cover the field adequately and satisfactorily. It is hoped that the scientific and commercial value of such work will come to be more generally recognized, and that a more ample provision may be made for it in the near future.

Marine Semi-Diesel Engines. ANON. (*The London Times Engineering Supplement*, No. 490, August 27, 1915.)—So rapid has been the development of the semi-Diesel or hot-bulb motor that it now practically holds the field for all types of motor craft in which the engine installation is anywhere between 100 and 600 horse-power. Below the former figure the paraffin engine is still very largely used, while above 600 horse-power the Diesel engine is better, as a rule, since even this power necessitates a twin-screw arrangement with a hot-bulb installation.

The employment of hot-bulb engines for barges and cargo-carrying coastal vessels has long been common, and during the past year it has gained considerable ground in its application to tugs, for which it is eminently adapted. Some such vessels are now to be seen on the Thames, and others have recently been ordered. In the opinion of those who have had most experience in both steam and motor tugs of this type, it is probable that the steam-driven tug will in course of time give way entirely to that equipped with hot-bulb engines, since the economy to be effected by the employment of the cheap heavy oil suitable for hot-bulb motors will render the steam tug in comparison far too expensive to operate.

Voice Carried 4900 Miles by Radio. ANON. (*Electrical World*, vol. 66, No. 15, October 9, 1915.)—With a few notable exceptions, radio-telephone workers of the past have been so much given to making extravagant claims for their various instruments, and then failing to accomplish anything even remotely resembling the original promises, that it is gratifying to find a real accomplishment in the art not previously advertised.

The human voice was successfully carried across the continent by wireless telephony on September 29 by the American Telephone and Telegraph Company. Speech transmitted from the radio station at Arlington to Mare Island, San Francisco Bay, was also heard clearly at the Pearl Harbor station in Hawaii, 4900 miles away.

It had been known for some time that the American Telephone and Telegraph Company and the Western Electric Company had been experimenting in radio-transmission from the Arlington station of the United States Navy Department, the aërial of which was loaned for that purpose. That the results which would be secured were to be of such great importance and interest was hardly suspected, however. After a period of preliminary experimentation, in which the special apparatus of the telephone company was connected to the aërial supported from the three tall towers at Arlington, on August 27 a telephonic test was made from there to Darien, Isthmus of Panama, 2100 miles away. Satisfactory speech was actually transmitted between the naval stations at these points, and greater likelihood of success for the anticipated transcontinental test was thus indicated.

EARLY MUNICIPAL WATER WORKS AT PANAMA.*

BY

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MUNICIPAL engineering problems of the early period of American operations on the Isthmus of Panama occupy a more important place in the history of the canal than is indicated by the relative magnitude of the work involved. As an item in the total construction required for the successful completion of the canal, the municipal works are insignificant; but as an essential step in the sanitary renovation of the Canal Zone and the adjacent cities of Panama and Colon, these works must be accorded a position of considerable prominence.

It is the intention of this paper to record briefly certain phases of the water works construction at Panama, from the inception of the American work up to the time when yellow fever was practically eliminated from the Isthmus, or from July, 1904, to October, 1905.

The treaty between the United States and the Republic of Panama under which the United States acquired the right to construct the canal ceded to the United States the Canal Zone, with full sovereignty therein. The treaty likewise gave to the United States control of all health matters in the adjacent cities of Panama and Colon, and provided that the United States should construct water and sewerage systems in those cities, stipulating that rates collected should be sufficient for the amortization of the cost, principal and interest, in fifty years.

The formal transfer of the canal properties from the French Company to the United States took place May 4, 1904, and shortly thereafter the Isthmian Canal Commission proceeded to exercise the rights conferred by the treaty. Mr. John F. Wallace, Chief Engineer, and Col. William C. Gorgas, Chief Sanitary Officer, arrived on the Isthmus the latter part of June, and active

* Abstract of a paper presented at the meeting of the Mechanical and Engineering Section, held Thursday, March 4, 1915.

steps in organization, sanitation, and preparation to build the canal began immediately.

When this work started, Panama City had a population of about 20,000. It had no public water supply. The inhabitants depended upon cisterns and an irregular dispensing by wagons which brought water from certain wells on the outskirts of the town. The city had no sewer system, although a few inadequate underground drains existed which were more of a sanitary nuisance than a benefit.

Colon had a population of about 8000. The Panama Railroad Company had a water supply in that city capable of delivering about 60,000 gallons a day. But, as this water was required for railroad, steamship, and allied purposes, the residents depended upon cisterns and similar collectors, as was the case in Panama. The railroad supply, moreover, was drawn from a watershed area of twenty-four acres back of Mount Hope, on which about fifty people were resident. As no sanitary precautions were taken, the use of the water for domestic purposes was at least questionable.

The Panama Railroad Company had installed in Colon one or two small sewers serving their works, but the city proper was even more lacking in sanitary drainage facilities than was the city of Panama.

Several of the construction towns along the line of the canal, such as Paraiso, Culebra, Empire, Gorgona, and Bohio, had been furnished by the French Company with water from nearby springs or streams. These supplies were incomplete and inadequate, being limited to providing water for bathing at a few buildings. The chief reliance was tanks and cisterns, as in the cities of Panama and Colon.

In brief, the lack of public water supplies resulted in tanks, cisterns, barrels, and similar receptacles being universally prevalent throughout the entire line of the canal, with a great concentration of such containers at the critical terminal points of Panama City and Colon. These receptacles formed ideal breeding places for the *Stegomyia*, or yellow-fever transmitting mosquito. These mosquitoes do not breed in the open swamps or larger bodies of water, but require the protection of buildings, grass, and foliage. Until household water containers could be eliminated by the substitution of modern water works and the accompanying sewers, it was a practical impossibility to exterminate the *Stegomyia*. Yel-

low-fever control at the Isthmus, then, was very largely a question of the early introduction of water supplies.

Very little yellow fever existed on the Isthmus when the Americans assumed control. The entire population was practically immune. With the arrival from the United States of hundreds of non-immunes, however, the situation changed. Yellow-fever cases gradually increased, until in June and July of 1905 the conditions approached those of an epidemic. At this critical period the laying of water mains in Panama City had sufficiently advanced to permit turning on the supply, with an accompanying decrease in cisterns and other water receptacles. The drop in yellow fever was at once apparent, as is shown in the following table:

	Deaths
July, 1904–January, 1905, inclusive	13
February, 1905	6
March	4
April	2
May	8
June	19
July	13
August	9
September	4
October	2
	80

Only the infinite patience, unremitting efforts, and constant vigilance of Colonel Gorgas and the sanitary corps working under his direction, coupled with skill and experience, prevented a veritable epidemic, handicapped as they were by the presence of thousands of mosquito-breeding foci. With the elimination of these breeding places, the triumph of the sanitarian was complete.

From the beginning, Panama City was looked upon as the centre from which the introduction and spread of yellow fever was most to be feared. This city had constant communication with South American ports where yellow fever was endemic, and a single imported case escaping quarantine regulations would be sufficient to spread serious trouble. The water supply for that city was therefore considered of primary importance. It was not a question of the best system, but a matter of how soon a suitable supply could be introduced. The selection of a permanent

source could very well be left until the plans for the canal were sufficiently developed to determine what relation the water supply would bear to that major product.

Some years prior to 1904 a project for a water supply for Panama made some progress until stopped by a revolution. The Juan Diaz River, some fifteen miles to the east of the city, had been selected as the source. This was an excellent stream, but by no means as readily available for rapid introduction as the Rio Grande River, adjacent to the Culebra Cut, some ten miles from the city. Availability being a controlling factor, the Rio Grande was adopted for Panama, and a complete system of water works and sewers was worked out and submitted to the Canal Commission. The work thereunder was authorized by the commission on August 9, 1904.

Actual construction work was subject to many annoying delays and was carried out under difficulties and amid some confusion. The general situation on the Isthmus at this period has been the subject of sharp criticism, much of which is easily explained at this time and at this distance from the actual work.

From the present viewpoint, it is apparent that a large part of the confusion attending the early Panama construction was due to the too prevalent American characteristic of hurry and rush without adequate preliminary preparation. The French Companies had failed in their effort to construct the canal. With the typical and commendatory American desire to make the canal a success, and break all speed records, the motto of "Now let the dirt fly" was impressed on those in charge. Immediate results in actual canal construction were demanded, irrespective of whether or not conditions were ripe for such work.

As a matter of fact, at the time the United States began operations there were about six hundred laborers, largely Jamaica negroes, actually at work upon the canal. There were, in addition, about five hundred more laborers scattered throughout the Isthmus who were possibly available to augment this force actually at work. A large percentage of this body of men was incapacitated to some degree by malaria fever, so that as a potential force for real work under American standards the numbers above given should be greatly decreased. Moreover, the entire plant and equipment turned over to the Americans was inadequate, out of repair, and generally inefficient and insufficient.

At the time water works construction was begun the Department of Health was organizing to put hospitals in shape, to cut down vegetation, to ditch, drain, and fumigate. The Building Department was getting ready to repair old houses, to make them habitable, and to build new ones. The Material and Supply Department was sorting old French stock, revamping the storehouses, and preparing to receive stores and deliver supplies. The Mechanical Department was putting the shops in order and repairing some of the machinery.

Transportation for all this work was practically limited to the Panama Railroad, which was barely able to handle ordinary trans-isthmian business, and entirely unable to cope with the additional operations incident to the canal work. Steamship docks were lacking, so that the necessary increased shipments of freight were almost out of the question.

Available for all work, there were perhaps a thousand or twelve hundred inefficient and incompetent Jamaica negroes. Each department needed more men, and yet no more men were wanted on the Isthmus until there was opportunity to house them, until water and food were ready, until there was provision to care for them if they should be sick. Each department depended upon and needed the other departments, and yet in a sense they were rivals.

With these handicaps and with the inherited incubus of disease and fevers not yet overcome, conditions governing work were necessarily somewhat primitive. Yet work on the Isthmus kept pace with the deliveries of supplies. To quote from a report of the Governor of the Canal Zone, under date of February 20, 1905: "It is now the middle of the dry season, water is scarce and very dear, and no increase in the supply can be expected from the new aqueduct for many months. The laying of the pipe is being done with expedition, and, in fact, a single cargo of water-pipe that has already been received was almost laid—every joint of it—before the last train-load pulled out from the railroad station. The pipe is sufficient in quantity to reach Pedro Miguel, but there now must be a wait of several weeks—and, I fear, months—before it can be completed."

Notwithstanding various obstacles, the water was finally introduced in the city of Panama, July 4, 1905. To quote from the report for that year of the Isthmian Canal Commission: "The

water was turned on for the first time on July 4th of this year. It would be difficult to describe the gratification and gratitude of the inhabitants at the consummation of their long-deferred hope. Formal expression took the form of a special session of the Municipal Council and the adoption of resolutions of thanks and the appointment of a committee to present a copy thereof to the Governor of the Zone. The *Te Deum* was sung in the Cathedral, attended by President Amador and his cabinet and the principal officials of the commission on the Isthmus and of the government of the Canal Zone."

The water supplies for Colon and the various towns along the line of the Canal followed the introduction of the water system in Panama. As before stated, yellow fever was put under control, and its definite elimination was begun from the time of that introduction. As an important factor in the sanitation of the canal, the water supplies cannot be overlooked.

September 24, 1915.

Ultra-violet Radiation and the Eye. W. E. BURGE. (*Transactions Illuminating Engineering Society*, September 20–23, 1915.)—It has been recognized for some time that, unless protected by a glass globe, the radiation from a quartz mercury arc or from an iron arc or from any light source emitting large quantities of ultra-violet rays is harmful to the eye. In a general way it has been assumed that all radiation of shorter wave-lengths than 350 $\mu\mu$ is injurious to living tissues. An organ (*e.g.*, the eye) is composed of tissues—connective tissue, nervous tissue, etc. The tissues are composed of cells. Ultra-violet radiation kills living cells and tissues by changing the protoplasm of the cells in such a way that certain salts can combine with the protoplasm to form an insoluble compound or coagulum.

Cataract is an opacity of the crystalline lens. Many observers have demonstrated that it is impossible to produce an opacity of the lens or cataract in a normal living animal by exposure of its eye to ultra-violet radiation. Analyses of human cataractous lenses from America show a great increase in the salts of calcium and magnesium, and those from India show, in addition to these salts, silicates. Glass blowers who develop cataract form a relatively small proportion of those engaged in that occupation, and it is assumed that those who do develop it have a disturbed condition of nutrition, which expresses itself in an increase of those substances which can precipitate the portion of the lens acted upon by ultra-violet radiation.

An opacity of the lens or cataract can be produced in fish living in solutions of those salts, found to be greatly increased in human cataractous lenses, by exposing the eye of the fish to ultra-violet radiation. This cannot be done with fish living in tap-water.

THE CONDUCTIVITY AND VISCOSITY OF SOLUTIONS OF ELECTROLYTES IN FORMAMID.*

BY

P. B. DAVIS, W. S. PUTNAM, and HARRY C. JONES.

THE work of Jones and his collaborators in the field of non-aqueous solvents, and in mixtures of these solvents with one another, thus far included a comprehensive study of both the conductivity and viscosity of typical salts in methyl and ethyl alcohols, in acetone and in glycerol; as well as in binary and ternary mixtures of these solvents with one another and with water. A review of all this work is to be found in Publication of the Carnegie Institution of Washington No. 210, Chapter 7.

Because of the somewhat limited solubility of electrolytes in most organic solvents, the scope of this work has necessarily been somewhat limited in the case of the pure liquids themselves. This is especially true with acetone and the alcohols. Glycerol, however, notwithstanding its high viscosity, proved to be a remarkably good solvent.

Among the few remaining liquids suitable for such work, the one used in this investigation—formamid—is, perhaps, the most important.

The fact that it has been studied so little in the past must be attributed to the difficulties encountered in obtaining a product pure enough for conductivity purposes, and to its relatively high price.

PREVIOUS WORK IN FORMAMID.

Until quite recently no investigation of the physical chemical properties of this remarkable liquid had been made. A brief sketch of the recent work is given below.

In his preliminary paper on organic solvents, Walden mentions the marked similarity of formamid to water as compared with other liquids in its solvent action on inorganic salts, and in

* Communicated by Dr. Harry C. Jones.

This investigation was carried out with the aid of a grant from the Carnegie Institution of Washington to H. C. Jones, and will form a part of its Publication No. 230.

later papers he records some of its physical constants in comparison with other amids and with water, viz., the dielectric constant and association factors,[1] specific conductivity and molecular conductivity of the normal electrolyte $N(C_2H_5)_4I$[2] and the viscosity.[3] All of these constants were obtained with a product which, as will be shown later, was far from pure; although it may be pointed out that the first two constants are not appreciably affected by small changes in the purity of the solvent.

Turner and Merry,[4] in their work on the molecular composition of trivalent nitrogen compounds, pointed out that the high association factor of formamid is one of its most striking characteristics, and they observed its similarity to water. They noted also that the association of formamid diminishes more rapidly with rise in temperature than that of water, and suggested that the solvent power for salts was largely due to its high molecular complexity. Somewhat later, Walden,[5] in a study of the temperature coefficient K, for organic liquids in the Ramsay and Shields equation for molecular surface-tension, found that in the case of formamid the value was far below that for non-associated liquids (2.12), having only the value 0.594–0.710, and from these data obtained an association factor in close agreement with that as determined by Turner and Merry.[6]

Dunstan and Kassel,[7] while determining the fluidity of various binary mixtures, measured the viscosity of mixtures of formamid and *i*-amyl alcohol at both low and somewhat elevated temperatures, and noted a pronounced minimum in the fluidity curves at about 60 to 70 per cent. of formamid at both temperatures; and also a slight maximum at about 10 to 20 per cent. formamid for the lower temperature.

Rohler[8] studied the solvent properties of formamid for organic salts, and also the electrolysis of its solutions. He compared the density with that of water above the freezing-point

[1] *Zeit. phys. Chem.*, **46**, 145, 175 (1906).
[2] *Ibid.*, **54**, 179 (1905).
[3] *Ibid.*, **55**, 230 (1906).
[4] *Journ. Chem. Soc.*, **97**, 2076 (1910).
[5] *Zeit. phys. Chem.*, **75**, 555 (1910)
[6] *Loc cit.*
[7] *Zeit. phys. Chem.*, **76**, 367 (1911).
[8] *Zeit. Elektrochem.*, **16**, 420, (1910).

and found no minimum, as in the case of the latter, but that the solvent expanded linearly with rise in temperature; the variation of the specific volume being represented by $V = 0.8674 \times (1 + .000742t)$.

Rohler also found that, according to Faraday's law, copper dissolves in formamid at all dilutions, half as univalent and half as bivalent ions at the anode, and obtained a good separation of copper with a weak current; but with a stronger current the metal separated as a dark slime.

Similar results were obtained with lead, zinc, and tin. With all of these metals in air more metal dissolved at the anode than separated at the cathode. The electrolysis of nickel, cobalt, iron, aluminum, and magnesium salts yielded no appreciable amount of metal at the cathode.

Rohler also noted the formation of metallic formamidates, and also of crystalline double compounds, which will be considered in discussing the properties of formamid as compared with those of water.

In a quite recent paper Walden[9] gives an account of his cryoscopic work in this solvent. In his preliminary discussion he states as his reason for adopting the freezing-point rather than the conductivity method for measuring dissociations, that the high specific conductivity of the solvent (as measured by him) rendered it impossible to obtain accurate data by the latter method. However, as will be pointed out later, by our method of preparation, formamid with a specific conductivity comparable with that of water, may be obtained with a loss of material only one-third that experienced by Walden.

Walden determined the freezing-point constant of formamid, and gives the value 35.0 as the mean of six determinations using urea, acetic, ester, diethylsulphite, ethyl acetate, mesityl oxide, and nitraniline respectively as the solute.

He also studied the dissociation of a number of electrolytes, including salts and both strong and weak acids, and pointed out that all binary salts are strongly ionized at relatively high concentrations; the ionization increasing slowly to the limit $\alpha = 100$ as in water; the limit, however, being reached at a smaller dilution in formamid.

[9] *Bull. Imp. Acad. Sci.*, St. Petersburg (1911).

The same was found to hold for acids, except in the case of those where combination took place between solvent and solute, as in the case of some of the strong acids; the values found being smaller than those for water.

FORMAMID AS A SOLVENT.

Formamid is a clear, colorless, and somewhat viscous liquid, melting at about 18°, and boiling under atmospheric pressure with partial decomposition at 200° to 212°. It reacts neutral to litmus and is quite hygroscopic, undergoing a slow hydrolysis at ordinary temperature into ammonium formate.

This solvent is the most closely allied to water in its properties of all the organic solvents. The two are miscible in all proportions, neither being soluble to any extent in absolute ether, chloroform, benzol, hexane, etc.; nor do they dissolve appreciably the aromatic hydrocarbons, nitrobenzol, fats, oils, etc.

Further similarity may be traced in their solvent action on metallic salts, thus: in the cold, cobalt and nickel salts yield solutions in formamid, similarly colored with those in water; although in some instances the formamid solutions undergo change in color on warming, which is probably due to a predominance of the unionized salt, since formamid undergoes a much sharper decrease in association with rise in temperature than water.

As Walden has pointed out, the similarity between water and formamid is still more wide-reaching. Phosphorus and sulphur are practically equally insoluble in both, while iodine gives a brownish-yellow solution. Starch is also soluble in formamid with formation in concentrated solution of a jelly; and on addition of formamid solution of iodine the starch solution turns intensely blue. The color, however, is less permanent than in water, owing to the slow action of the iodine on the solvent. The fluorescent dyes also exhibit like phenomena in formamid and in water, this being particularly marked in the case of eosin.

Bruni and Manuelli [10] further show that just as water hydrolyzes the salts of weak bases, such as those of bismuth and antimony, forming unstable basic salts, formamid, by a process of amidolysis, may form basic salts of these same metals; and Rohler,[11] in extending this work, has isolated characteristic basic

[10] *Zeit. Elektrochem.*, 11, 554 (1905).
[11] *Ibid.*, 16, 418 (1910).

salts of copper, cobalt, nickel, and zinc. He also obtained amidates similar to hydrates, of which $PbCl_2.HCONH_2$ is an example; as well as metal formamidates having the general composition $Me(HNCOH)_22HCONH_2$, where Me may be either copper, nickel, cobalt, or zinc.

In addition to the above, Rohler has noticed the formation of well-defined crystalline compounds of formamid with the halogen acids corresponding to the well-known mono-, di- and trihydrates.

As is now a well-established fact, the dielectric constant of the solvent is a measure of its own association, and therefore a measure of its dissociation power for electrolytes. Of the common solvents water has the highest dielectric constant, and is the best dissociant. Formamid, however, has a higher dielectric constant than water, as will be shown by referring to the following table of physical constants of the two solvents, and should therefore be a better dissociant, which will be pointed out in our discussion.

TABLE I.

Molecular weight	Water 18	Formamid 45
Melting-point	0°	1.5–2.1 (Walden)
Boiling-point 760 mm.	100°	200–212
Density 0°/4°	.9999	1.151 (Walden, Davis)
Dielectric constant	81 (Drude) 25°	84 (Walden)
Association factor 30°	3.81 (Ramsay-Shield)	6.18 (Turner and Merry)
K—surface tension 20°–30°		0.65 (Turner and Merry)
Minimum specific conductivity	$4. \times 10^{-8}$	2.8×10^{-6} (Davis and Putnam)
Average specific conductivity working values	1.5×10^{-6}	2.7×10^{-5} (Davis and Putnam)
Viscosity 25°	0.00891 (Thorpe and Roger)	0.0324 (Davis)
Dissociation of $N(C_2H_5)_4I$ at V = 100	91%	93% (Walden) 98% (Davis and Putman)

PURIFICATION OF THE SOLVENT.

It might be well to note at the outset that neither a clean melting-point nor a constant boiling-point is a sufficient criterion for the purity of the solvent for conductivity purposes; since it has been found by ourselves and others that a constant boiling liquid such as formamid may be separated into fractions of widely different specific conductivities. That this is true is due no doubt

in this particular case to the fact that minute quantities of the products of hydrolysis, such as would have no measurable effect on the apparent boiling-point of the liquid, on account of the high dissociating power of the formamid, produce a marked increase in its conductivity.

The chief criterion, therefore, in judging of the purity of the solvent used in this investigation was its specific conductivity. The material with which we started was obtained from Kahlbaum, and had a specific conductivity of about 674×10^{-5}, or about that of tap-water. Samples obtained from Bender, and Hobein, Schuchardt, and from Hoffman and Kropff proved, from the conductivity standpoint, to be little or no better than the above.

As has already been pointed out, formamid is hygroscopic, forms a true solution with water, and subsequently undergoes slow hydrolysis into ammonium formate. The first problem, therefore, that presented itself, was the removal of any dissolved water not already acted on; and, second, the removal of the products of hydrolysis already present. The method of purification finally adopted made it necessary to design and construct suitable apparatus for distillation in comparatively high vacua.

A third problem presented itself in connection with the preservation and subsequent manipulation of the solvent and of solutions in it, in such a manner as to incur minimum exposure to moisture. In addition, the expense of the solvent made necessary the recovery of it with the least possible loss by decomposition from solutions of salts in this solvent.

The removal of dissolved water was finally effected by the use of carefully dehydrated sodium sulphate. After testing a number of other dehydrating agents, such as magnesium sulphate, calcium chloride, sulphuric acid, *in vacuo*, etc., it was found that sodium sulphate produced a smaller loss of materials from combination with it than any of the other dehydrating agents studied.

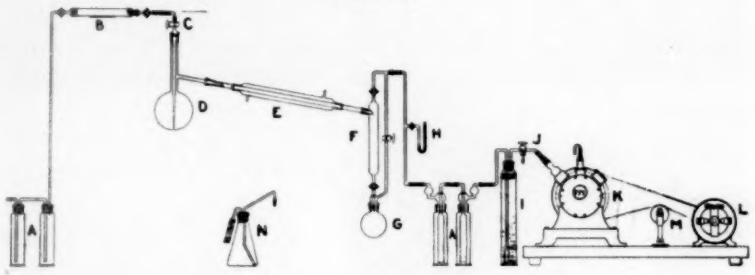
Formamid was therefore allowed to stand for several weeks over anhydrous sodium sulphate, in carefully sealed, glass-stoppered bottles placed in a cool, dark room. An attempt was made to effect a preliminary purification of formamid by fractional crystallization, but the end product, after several fractionations, invariably showed a higher conductivity than the original

substance. We were therefore forced to conclude, as were Freer and Sherman in preparing formamid, to study its sodium salts, that a properly conducted distillation process was the best one available.

The apparatus finally adopted for distillation is shown diagrammatically in Fig. 1; although by placing the various parts in parallel rows it was possible to mount the whole apparatus upon a desk space of only 2½ feet square, as is shown in the photograph Fig. 2.

In this apparatus, with all the stop-cocks closed, a vacuum of 0.5 mm. was easily maintained by the Gaede pump (Fig. 1, *K*). This pump was mounted, together with a $^1/_{12}$-horse-power motor (Fig. 1, *L*), connecting rheostat (not shown), idler (Fig. 1, *M*),

FIG. 1.

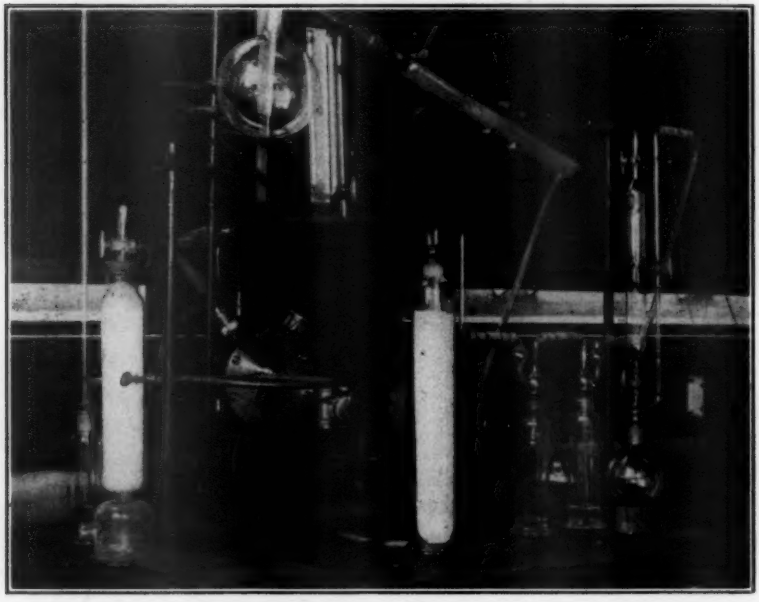


and switch, on a heavy maple-wood base, provided with carrying handles and rubber feet.

During the actual process of distillation, the vacuum rose to from 1.5 to 2.5 mm.; since, on account of the high viscosity of the liquid, it was necessary to keep a fairly rapid current of air flowing in through the stop-cock and drawn-out portion of the distillation head (Fig. 1, *E*), in order to keep the liquid agitated and prevent the violent bumping which usually attended distillation in a high vacuum. The drying of this current of air sufficiently, and the proper method of introducing it, proved to be one of the most serious difficulties encountered. The method finally adopted is shown in the figure. The air, before entering the distillation flask, passed through a soda line tower (not shown in the drawing, but appears on the left in Fig. 2), then

through the two wash bottles (Fig. 1, *A*), and finally over phosphorus pentoxide contained in the long tube *B*, which was protected by two glass stop-cocks, the one sealed permanently into the tube and the other securely fastened with sealing wax in the left-hand tapered end of *B*. This joint made it possible to open *B*, in renewing the phosphorus pentoxide. From *B* the current of air passed into *C*, through a short rubber connection and a right-angle glass bend; the open end of which is connected with *C* by a rubber joint made air tight with rubber cement.

FIG. 2.



The distillation head *C* consisted of a short projecting tube, a well-ground stop-cock of large bore; the ground connection with the 750-cubic centimetre distilling flask *D*, and the long inner tube reaching to the bottom of the flask and drawn down to a capillary at the end, so as to cause the air to bubble in a fine stream through the liquid. Connection between the flask and the condenser was effected by a ground joint designed to prevent the liquid distilling over, from coming in contact with the stop-

cock grease used in making the joint air-tight. The condenser was also ground into the Axtell receiver *F*, which is too well known to require further description, other than to state that the capacity of the barrel was about 100 cubic centimetres, and that of the small bulb 250 centimetres. The receiver allowed the removal of different fractions without interrupting the vacuum.

The receiver was connected with the pump *K*, through the gas wash bottles A^1, the soda lime tower *I*, and the three-way stop-cock *J*. One of the wash bottles was filled just to the upper level of the holes in the inner cylinder with sulphuric acid; the other being empty and serving as a trap in the case of back pressure. The construction of the wash bottles secured a maximum exposure of acid to the possible alkaline vapors (NH_3) without appreciable back pressure.

Liquid formamid was introduced into the flask at any time during the distillation without destroying the vacuum, by closing the stop-cock on *C*, temporarily disconnecting the air inlet, and attaching at the same point the flask and syphon *N*. On opening the stop-cock the diminished pressure in the flask drew in any liquid in *N*.

During the distillation the flask was immersed in a bath of hardened cottonseed oil ("Crisco"), into which the thermometer dipped. Ordinary rectified cottonseed oil was first used, but this was soon discontinued, since the oil quickly became rancid and offensive when heated. The "Crisco," however, remains sweet and untainted even after continued use. The temperature in the outer bath was maintained at from 10° to 15° higher than the boiling-point of the liquid at a given pressure; the usual temperature being 100° to 115°. In the apparatus used in the preliminary work a thermometer was sealed into the air inlet tube of *C*, with its bulb well down in the flask, and the boiling-point of the liquid observed; but this thermometer was subsequently discarded and the temperature controlled solely by the thermometer in the outer bath, so as to obtain about 100 cubic centimetres of distillate every 15 minutes.

As a rule, starting with Kahlbaum's so-called c.p. formamid, from three to four distillations yielded a product sufficiently pure for our purpose. The decrease in the conductivity with successive distillation is shown in the following table:

		Specific Conductivity.
Original Material		674.0×10^{-5}
First distillation	First fraction	785.8×10^{-5}
	Second fraction	435.0×10^{-5}
	Third fraction	112.3×10^{-5}
Second distillation	First fraction	204.2×10^{-5}
	Second fraction	153.8×10^{-5}
	Third fraction	67.4×10^{-5}
Third distillation—first fraction		24.6×10^{-5}
		10.3×10^{-5}
		4.8×10^{-5}

While the end fraction in this case was sufficiently pure for use, a fourth distillation yielded a product with the conductivity of about $3\text{–}4 \times 10^{5}$; although the exact minimum conductivity of this solvent has thus far not been ascertained, we have obtained small lots with a specific conductivity of $2.8 \times 10,^{-6}$ or from two to three times the value for the conductivity water used in this laboratory. Walden used in his work a product with a conductivity of 7.5×10^{-4}, but obtained a small fraction of about 10 per cent. of the original material, with a conductivity of 4.7×10^{-5}. Our solvent was from 35 to 40 per cent. of the original volume with a maximum specific conductivity of 4.8×10^{-5}, with a minimum of 1.37×10^{-5} and an average of 2.7×10^{-5}.

SALTS.

On account of the instability of the solvent formamid in the presence of moisture, the salts used in this investigation were all dehydrated with special care at the highest temperature which it was possible to use for these substances.

SOLUTIONS.

The more concentrated solutions in formamid were made up by direct weighing; the more dilute by diluting the more concentrated. This operation was much facilitated by the use of two burettes holding 50 and 10 centimetres respectively; the one being employed for the solvent, the other for the one-tenth normal solution. Each burette was connected with the reservoir containing the solvent or the solution by a siphon provided with a glass stop-cock; and access of moisture being prevented by calcium chloride tubes connected with both the burettes and the reservoirs.

The solvent was kept until required in half-litre glass-stoppered Erlenmeyer flasks, and the solutions when made up were

preserved in 35 c.c. flasks of similar design, which were sealed with rubber cement.

On account of the high price of the solvent, only 25 cubic centimetres of each solution was prepared; this amount serving both for conductivity and viscosity measurements. All operations in preparing the solutions were carried out at 20°.

CONDUCTIVITY APPARATUS.

The conductivity apparatus used in this investigation was identical with that employed in our earlier work on binary and ternary mixtures of water, acetone, and glycerol; the method of obtaining duplicate readings and other details being exactly the same as in the earlier work, with the exception of the use of a rocking commutator with mercury contact, instead of the two-blade, double-throw switch used in reading both ends of the bridge; the object being to eliminate as nearly as possible all external resistance.

The conductivity cells were also of the type recently employed in this laboratory for work with non-aqueous solvents, and were carefully standardized at regular intervals.

VISCOSITY APPARATUS.

The apparatus used in this work was essentially the same as in our earlier investigations. We have designed and used an improved support for the viscometers, which is particularly well adapted to our new thermostat. A new pyknometer * has also been devised, which has proved to have advantages over the older form.

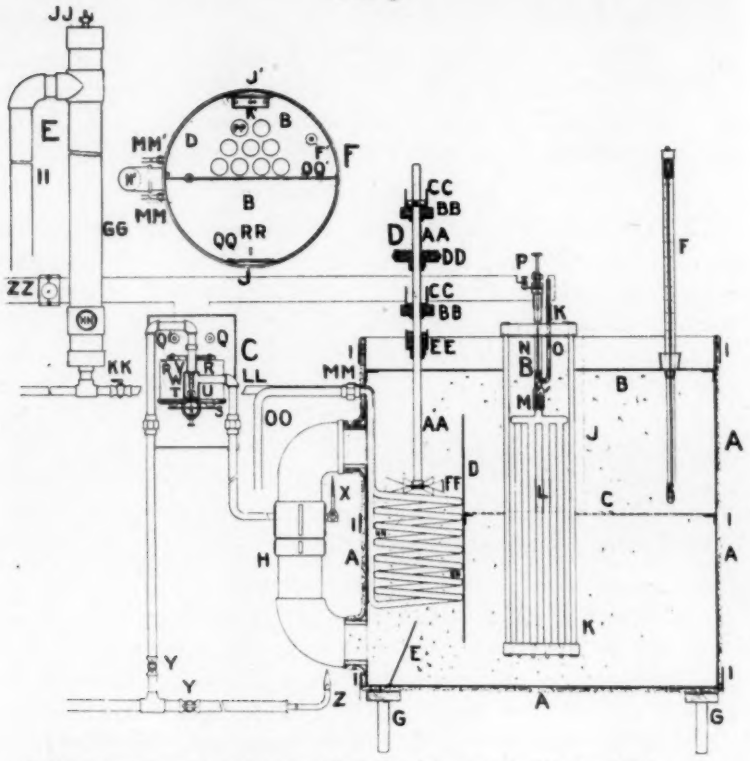
THERMOSTATS.

The new form of constant temperature bath for conductivity and viscosity investigations, which has already been fully described in Chapter 6 of the Publication of the Carnegie Institution of Washington, No. 210, has already met with such approval that by request it is here described in some detail.

These thermostats are substantially constructed of copper and use gas for maintaining constant temperature; the heat being applied directly to a heavy galvanized iron pipe (Fig. 3, *A–H*), outside the bath, through which a part of the water is kept circulating by means of the propellers (*FF*). This mixes with the remainder of the water in the space enclosed by the cooling coils (*NN*), and the diaphragm *I*. By this means a very even distribu-

* *Jour. Am. Chem. Soc.*, **37**, 1199 (1915).

FIG. 3.



Constant temperature apparatus used in conductivity and viscosity investigation.

A. Sixty-litre Bath of 20-ounce Copper:

(A) Asbestos insulation; (B) sheet-brass cover; (C) woven wire grid; (D) semicircular diaphragm; (E) deflector to divert part of the water into the heater pipes; (F) thermometer; (G) tripod; (H) galvanized iron heater pipes attached to bath with 1½-inch brass nipples; (I) brass bands supporting insulation; (J) outline of windows shown also in *F*.

B. Thermostat:

(K) Holder; (L) toluol reservoir tubes with ¼-mm. walls. (M) expansion chamber partially filled with mercury; (N) 1.5-mm. capillary; (O) side arm with sealed-in platinum contact.

C. Gas Flow Regulator:

(Based on "steel block" devised by E. E. Reid, *Amer. Chem. Journ.*, 41, 151, and improved by others.)

(Q) Binding posts to coils; (R) magnet coils; (S) armature; (T) steel valve-chamber; (U) plunger, with rubber washer and mercury seal, working against end of gas-supply pipe (V) and wire to armature (S); (W) needle valve to regulate size of pilot flame (shown as dotted circle); (X) microburner with needle valve; (Y) gas-cocks regulating supply to relay and rough heater; (Z) high-voltage lamp spanning spark-gap of thermostat.

D. Stirring Mechanism:

(AA) Shaft; (BB)-shaped bracket supporting (CC) oil cups and journals; (DD) pulley with oil trap filled with waste; (EE) oil trap; (FF) six-bladed 3¼-inch propeller.

E. Cooling System:

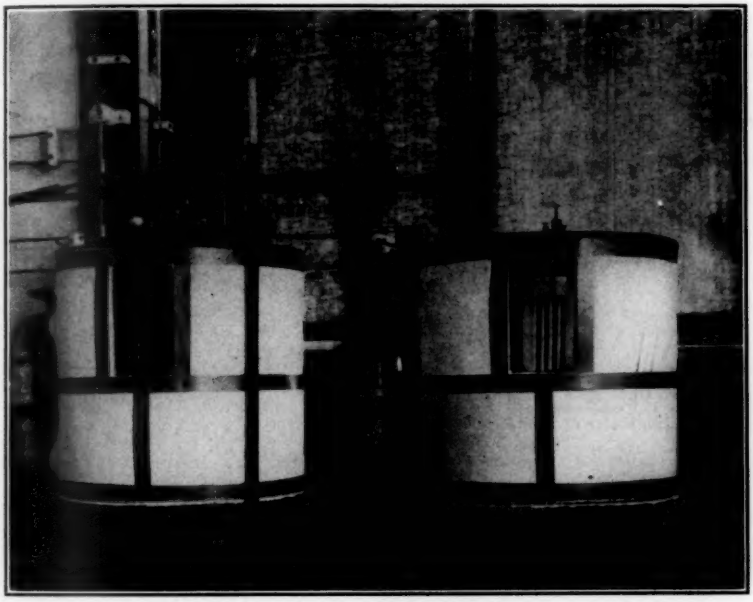
(GG) Standpipe; (HH) supply; (II) overflow; (JJ) pet-cock in cap; (KK) regulating valve to coils; (LL) inlet pipe to coils; (MM) interchangeable unions (here ice- or hot-water coils may be inserted for very low or high temperatures); (NN) cooling coils; (OO) waste pipe.

F. Diagram of Top (smaller scale):

(B), (D), (F), (H), (J), and (K) the same as in *A;* (MM) same as in *E;* (PP) apertures in cover for conductivity cells; (QQ) lugs supporting cover; (RR) handle to removable section of cover.

tion of heat is obtained, and because of the large heat capacity of the bath itself, these thermostats are insensible to other than marked changes in room temperature. The improved toluol regulator (Fig. 1, *B*), mentioned in our publication on conductivity and viscosity in ternary mixtures, and described in detail elsewhere,[12] was used to operate the relays controlling the gas-supply to the micro-burners of the thermostats. The gas valve shown in the illustration is an improvement made by others on the steel

FIG. 4.



block devised by E. E. Reid, and was used throughout the greater part of this work. Subsequently, however, a new type of valve was devised here for eliminating the expensive telegraph relay and the mercury seal of the plunger *U*. Preliminary tests have shown this valve to have decided advantages over the former thermostats; and should it prove satisfactory a complete discussion will appear later. There are at present in this laboratory seven

[12] *Journ. Amer. Chem. Soc.*, **37**, 1198 (1915).

such thermostats in use, and they are capable of maintaining temperature uniform to within 0.01° at 15° and 35°, and to within 0.003 to 0.005 at 25°. The thermostats used in this laboratory are all driven by a single $\frac{1}{12}$-horse-power, direct-current motor. The complete baths are shown in Fig. 4.

Both conductivity and viscosity measurements were made at 15°, 25°, and 35°; the data are tabulated in the usual manner, tables of constants and the use of a calculating machine greatly facilitating the calculations.

TABLE II.

Comparison of the Various Solvents.

Solvent	Dielectric constant	Association factor	Viscosity at 25°
HCN	95		
$HCONH_2$	94	6.18	0.0326
H_2O	81.7	3.81	0.0089
CH_3OH	32.5	3.43	0.0056
C_2H_5OH	21.7	2.74	0.0111
$C_3H_5(OH)_3$	16.5	1.80	5.854
$CH_3-CO-CH_3$	20.7	1.26	0.0035

TABLE III.

Sodium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	11.83	15.53	19.76	62.1	63.1	63.4
4	13.80	18.01	22.82	72.4	73.2	73.6
10	16.20	21.09	26.64	85.0	85.7	86.0
50	17.46	22.62	28.55	91.6	91.9	92.1
200	18.79	24.36	30.59	98.6	98.9	98.7
400	19.06	24.62	30.99	100.0	100.0	100.0
*K	1.53×10^{-5}	1.99×10^{-5}	2.46×10^{-5}			

*K is the specific conductivity of the solvent

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0313	0.0272	0.370	0.423
4	0.0305	0.0267	0.421	0.481
10	0.0302	0.0263	0.489	0.555
50	0.0296	0.0262	0.516	0.593
200	0.0296	0.0256	0.557	0.623
400	0.0292	0.0259	0.0556	0.637

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05578	0.04081	0.03120	17.93	24.50	32.05
4	0.04883	0.03678	0.02837	20.48	27.19	35.25
10	0.04523	0.03413	0.02666	22.11	29.30	37.51
Solv.	0.04274	0.03194	0.02511	23.40	31.31	39.83

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0367	0.0308
4	0.0328	0.0296
10	0.0325	0.0280
Solv.	0.0338	0.0272

TABLE IV.

Sodium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	11.92	15.71	20.01	64.7	65.6	66.1
4	14.17	18.57	23.59	76.9	77.5	78.0
10	15.91	20.67	26.05	86.3	86.3	86.1
50	17.17	22.33	28.17	93.2	93.2	93.1
200	18.27	23.80	29.98	99.1	99.3	99.1
400	18.43	23.96	30.25	100.0	100.0	100.0
K	2.23×10^{-5}	2.83×10^{-5}	3.48×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0318	0.0274	0.379	0.430
4	0.0311	0.0270	0.440	0.502
10	0.0299	0.0260	0.476	0.538
50	0.0301	0.0262	0.516	0.584
200	0.0303	0.0260	0.553	0.618
400	0.0300	0.0263	0.553	0.629

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05425	0.03997	0.03065	18.43	25.02	32.63
4	0.04822	0.03640	0.02800	20.74	27.47	35.71
10	0.04532	0.03381	0.02653	22.07	29.58	37.69
Solv.	0.04307	0.03302	0.02570	23.22	30.29	38.91

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15 –25°	25 –35°
2	0.0357	0.0304
4	0.0325	0.0300
10	0.0340	0.0274
Solv.	0.0304	0.0285

TABLE V.

Sodium Chromate in Formamid.

MOLECULAR CONDUCTIVITY.

V	Molecular conductivity 15°	25°	35°
10	24.57	33.66	42.66
50	31.46	41.48	52.18
200	34.34	44.82	56.38
400	39.00	50.79	.....
800	42.64	55.07	69.16
1600	72.06	93.51	116.44
K	1.30×10^{-5}	1.65×10^{-5}	2.03×10^{-5}

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
10	0.0316	0.0267	0.809	0.900
50	0.0319	0.0258	1.002	1.070
200	0.0305	0.0258	1.048	1.156
400	0.0302	.....	1.179	.....
800	0.0292	0.0256	1.243	1.409
1600	0.0298	0.0245	2.145	2.293

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
10	0.04966	0.03633		20.14	27.30	
Solv.	0.04301	0.03221		23.25	31.05	

TABLE VI.

Potassium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.12	18.25	22.94	67.9	68.3	68.7
4	16.15	20.84	26.13	77.6	78.0	78.3
10	18.06	23.27	28.99	86.8	87.1	86.8
50	19.27	24.94	31.12	92.6	93.3	93.2
200	20.66	26.60	33.10	99.3	99.5	99.1
400	20.80	26.73	33.39	100.0	100.0	100.0
K	2.94×10^{-5}	3.75×10^{-5}	4.69×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0292	0.0257	0.413	0.469
4	0.0290	0.0252	0.469	0.529
10	0.0288	0.0246	0.521	0.572
50	0.0294	0.0248	0.567	0.618
200	0.0288	0.0244	0.594	0.650
400	0.0285	0.0249	0.593	0.666

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05251	0.03922	0.03000	19.04	25.50	33.33
4	0.04724	0.03572	0.02794	21.17	28.00	35.79
10	0.04457	0.03386	0.02642	21.94	29.53	37.85
Solv.	0.04304	0.03256	0.02542	23.23	30.71	39.34

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0339	0.0307
4	0.0323	0.0278
10	0.0338	0.0282
Solv.	0.0322	0.0281

TABLE VII.

Potassium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	36°	Dissociation 15°	25°	35°
2	14.42	18.67	23.29	70.7	71.0	71.0
4	16.32	21.05	26.34	80.0	80.1	80.3
10	18.23	23.45	29.21	89.4	89.2	89.0
50	19.25	24.87	31.03	94.4	94.6	94.5
200	20.39	26.28	32.81	100.0	100.0	100.0
400	20.26	26.29	32.82			
K	2.23×10^{-5}	2.83×10^{-5}	3.48×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0295	0.0247	0.425	0.462
4	0.0290	0.0251	0.473	0.529
10	0.0286	0.0246	0.522	0.576
50	0.0292	0.0248	0.562	0.616
200	0.0289	0.0248	0.589	0.653

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04982	0.03710	0.02884	20.07	.....	34.67
4	0.04631	0.03525	0.02716	21.59	28.37	36.81
10	0.04418	0.03353	0.02629	22.64	29.82	38.04
Solv.	0.04307	0.03302	0.02570	23.22	30.29	38.91

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0343	0.0286
4	0.0314	0.0298
10	0.0318	0.0274
Solv.	0.0304	0.272

TABLE VIII.

Potassium Sulphocyanate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	15.15	19.10	24.28	70.0	69.2	70.4
4	17.42	22.31	27.87	80.6	80.8	80.8
10	19.04	24.38	30.35	88.0	88.3	88.0
50	20.02	25.61	32.16	92.6	92.8	93.3
200	21.21	27.19	33.89	98.1	98.5	98.3
400	21.62	27.60	34.47	100.0	100.0	100.0
K	1.07×10^{-5}	1.37×10^{-5}	1.69×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0261	0.0271	0.395	0.518
4	0.0281	0.0249	0.489	0.556
10	0.0280	0.0245	0.534	0.597
50	0.0279	0.0256	0.558	0.655
200	0.0282	0.0246	0.598	0.670
400	0.0277	0.0249	0.598	0.687

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04891	0.03657	0.02838	20.45	27.35	35.24
4	0.04585	0.03473	0.02713	21.81	28.79	36.86
10	0.04369	0.03280	0.02574	22.89	30.49	38.85
Solv.	0.04294	0.03258	0.02554	23.29	30.69	39.15

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0337	0.0287
4	0.0320	0.0280
10	0.0332	0.0274
Solv.	0.0314	0.0276

TABLE IX.

Ammonium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	16.31	20.85	25.79	70.6	70.6	70.0
4	18.21	23.31	28.88	78.8	78.9	78.3
10	20.57	26.21	32.53	89.0	88.7	88.3
50	21.82	27.94	34.82	94.4	94.6	94.5
200	22.63	28.83	35.93	97.9	97.6	97.5
400	23.11	29.54	36.86	100.0	100.0	100.0
K	2.94×10^{-5}	3.76×10^{-5}	4.67×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0278	0.0237	0.454	0.494
4	0.0280	0.0247	0.510	0.557
10	0.0274	0.0241	0.564	0.632
50	0.0280	0.0246	0.612	0.688
200	0.0274	0.0246	0.620	0.710
400	0.0278	0.0248	0.643	0.732

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04795	0.03607	0.02776	20.86	27.73	36.02
4	0.04550	0.03455	0.02680	21.98	28.94	37.31
10	0.04399	0.03273	0.02635	22.73	30.55	37.95
S.	0.04304	0.03256	0.02542	23.23	30.71	39.34

TEMPERATURE COEFFICIENTS.

V	15°–25°	25°–35°
2	0.0330	0.0299
4	0.0317	0.0289
10	.....	.....
S.	0.0322	0.0281

TABLE X.

Ammonium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	16.90	21.70	26.80	73.6	73.1	72.5
4	18.78	24.06	29.88	81.8	81.0	80.8
10	20.48	26.32	32.44	89.2	88.6	87.7
50	21.31	27.39	33.92	92.8	92.3	91.2
100	22.20	28.40	35.40	96.7	95.7	95.8
400	22.96	29.69	36.97	100.0	100.0	100.0
K	3.68×10^{-5}	4.71×10^{-5}	5.87×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25	25°–35	Conductivity units 15°–25	25°–35
2	0.0284	0.0281	0.480	0.610
4	0.0281	0.0240	0.528	0.582
10	0.0285	0.0233	0.584	0.612
50	0.0285	0.0238	0.608	0.653
100	0.0279	0.0246	0.620	0.700
400	0.0293	0.0245	0.673	0.728

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05091	0.03856	0.03007	19.64	25.93	33.26
4	0.04571	0.03417	0.02669	21.88	29.27	37.47
10	0.04367	0.03311	0.02607	22.90	30.20	38.36
Solv.	0.04201	0.03207	0.02496	23.80	31.18	40.06

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0320	0.0282
4	0.0292	0.0280
10	0.0319	0.0270
S.	0.0310	0.0285

TABLE XI.

Tetramethyl Ammonium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.62	18.72	23.38	68.6	68.5	68.1
4	16.92	21.80	27.27	79.4	79.7	79.4
10	18.37	23.65	29.32	86.2	86.5	85.4
50	19.64	25.32	31.65	92.1	92.6	92.1
200	21.19	27.34	34.11	99.5	100.0	99.3
400	21.30	27.34	34.35	100.0	100.0	100.0
K	1.53×10^{-5}	1.99×10^{-5}	2.46×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25	25°–35	Conductivity units 15°–25–	25°–35
2	0.0280	0.0249	0.410	0.466
4	0.0288	0.0251	0.488	0.547
10	0.0287	0.0240	0.528	0.567
50	0.0289	0.0250	0.568	0.633
200	0.0290	0.0248	0.615	0.677
400	0.0283	0.0256	0.604	0.701

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04775	0.03578	0.02791	20.94	27.95	35.83
4	0.04503	0.03427	0.02679	22.21	29.18	37.33
10	0.04394	0.03313	0.02601	22.76	30.18	38.45
Solv.	0.04274	0.03194	0.02511	23.40	31.31	39.83

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0335	0.0282
4	0.0314	0.0279
10	0.0326	0.0274
Solv.	0.0338	0.0272

TABLE XII.

Tetraethylammonium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	
2	11.78	15.42	19.47	62.6	63.5	64.0
4	13.86	18.10	22.78	73.7	74.5	74.9
10	15.74	20.31	25.31	83.7	83.6	83.2
50	17.60	22.69	28.47	93.6	93.5	93.6
100	18.45	23.79	29.85	98.1	98.0	98.1
200	18.81	24.28	30.43	100.0	100.0	100.0
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0309	0.0262	0.364	0.405
4	0.0306	0.0259	0.424	0.468
10	0.0290	0.0246	0.457	0.500
50	0.0298	0.0255	0.509	0.578
100	0.0289	0.0255	0.534	0.606
200	0.0291	0.0253	0.547	0.615

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04879	0.03618	0.02802	20.50	27.64	35.68
4	0.04573	0.03486	0.02687	21.87	28.69	37.22
10	0.04431	0.03336	0.02607	22.57	29.98	38.36
Solv.	0.04284	0.03256	0.02561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0349	0.0291
4	0.0312	0.0297
10	0.0328	0.0280
Solv.	0.0316	0.0271

TABLE XIII.

Rubidium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.28	18.46	23.10	67.7	68.1	68.6
4	16.31	21.00	26.17	77.3	77.5	78.0
10	18.77	24.09	30.10	89.0	88.9	89.3
50	19.84	25.54	31.82	94.1	94.3	94.4
100	20.59	26.49	33.03	97.6	97.8	98.0
200	21.09	27.08	33.69	100.0	100.0	100.0
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0292	0.0251	0.418	0.464
4	0.0288	0.0251	0.469	0.527
10	0.0283	0.0249	0.532	0.601
50	0.0287	0.0246	0.570	0.628
100	0.0287	0.0247	0.590	0.654
200	0.0284	0.0244	0.599	0.661

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05246	0.03869	0.02961	19.06	25.85	33.77
4	0.04773	0.03606	0.02778	20.95	27.73	36.00
10	0.04486	0.03396	0.2623	22.29	29.45	38.12
Solv.	0.04284	0.03256	0.2561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0356	0.0308
4	0.0324	0.0298
10	0.0321	0.0295
S.	0.0316	0.0271

TABLE XIV.

Rubidium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
4	16.36	21.26	26.52	79.8	81.1	81.2
10	18.47	23.79	29.63	90.1	90.8	90.7
50	20.49	26.21	32.68	100.0	100.0	100.0
100	20.36	26.27	32.71			
K	4.79×10^{-5}	6.07×10^{-5}	7.62×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25	25°–35	Conductivity units 15°–25	25°–35
4	0.0300	0.0247	0.490	0.526
10	0.0286	0.0245	0.532	0.584
50	0.0279	0.0247	0.572	0.647

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	Solution supersaturated at 25°					
4	0.04661	0.03501	0.02717	21.46	28.56	36.81
10	0.04462	0.03394	0.02648	22.41	29.46	37.76
Solv.	0.04312	0.03260	0.02564	23.19	30.68	39.00

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0331	0.0289
10	0.0315	0.0282
S.	0.0323	0.0271

TABLE XV.

Rubidium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.73	19.01	23.78	72.4	72.0	72.2
4	16.87	21.71	27.21	82.9	82.2	82.6
10	18.60	24.00	29.83	91.4	90.9	90.5
50	19.59	25.27	31.49	96.3	95.7	95.6
100	20.23	26.06	32.62	99.5	98.7	98.7
200	20.34	26.41	32.95	100.0	100.0	100.0
K	3.68×10^{-5}	4.71×10^{-5}	5.87×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0290	0.0251	0.428	0.477
4	0.0287	0.0253	0.484	0.550
10	0.0290	0.0243	0.540	0.583
50	0.0290	0.0246	0.568	0.622
100	0.0288	0.0248	0.568	0.646
200	0.0298	0.0248	0.607	0.654

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04945	0.03516	0.02865	20.22	27.66	34.90
4	0.04643	0.03503	0.02737	21.54	28.55	36.54
10	0.04432	0.03348	0.02634	22.56	29.87	37.97
S.	0.04201	0.03207	0.02496	23.80	31.18	40.06

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0368	0.0265
4	0.0325	0.0280
10	0.0324	0.0271
S.	0.0310	0.0285

TABLE XVI.

Rubidium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
4	16.20	20.79	25.85	77.7	77.6	77.6
10	18.85	24.07	30.00	90.4	89.8	90.1
50	20.22	25.97	32.23	97.0	96.9	96.8
100	20.85	26.80	33.31	100.0	100.0	100.0
200	20.76	26.68	33.02			
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25	25°–35	Conductivity units 15°–25	25°–35
4	0.0283	0.0243	0.459	0.506
10	0.0277	0.0246	0.522	0.593
50	0.0284	0.0241	0.575	0.626
100	0.0285	0.0243	0.595	0.651

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04586	0.03430	0.02673	21.81	29.16	37.41
10	0.04417	0.03346	0.02622	22.64	29.89	38.15
Solv.	0.04284	0.03256	0.02561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0337	0.0283
10	0.0320	0.0276
Solv.	0.0316	0.0271

TABLE XVII.

Cæsium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
4	16.83	21.69	27.15	78.6	78.8	78.7
10	18.75	24.09	30.03	87.6	87.5	87.1
200	21.40	27.54	34.49	100.0	100.0	100.0
400	21.06	27.15	34.11			
K	1.34×10^{-5}	1.72×10^{-5}	2.10×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
4	0.0289	0.0252	0.486	0.546
10	0.0285	0.0247	0.534	0.594
200	0.0287	0.0252	0.614	0.695
400	0.0289	0.0256	0.609	0.696

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04735	0.03578	0.02789	21.12	27.95	35.86
10	0.04481	0.03395	0.02654	22.32	29.46	37.68
Solv.	0.04317	0.03245	.....	23.16	30.18	.....

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0323	0.0281
10	0.0320	0.0279
Solv.	.....	

TABLE XVIII.

Cæsium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
4	17.00	21.79	27.10	78.2	78.1	78.3
10	18.90	24.23	29.92	86.9	86.8	86.4
100	21.36	27.42	33.99	98.2	98.3	98.2
200	21.75	27.90	34.61	100.0	100.0	100.0
400	21.59	27.64	34.43			
K	1.34×10^{-5}	1.72×10^{-5}	2.10×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
4	0.0282	0.0244	0.479	0.531
10	0.0282	0.0235	0.533	0.569
100	0.0284	0.0240	0.606	0.657
200	0.0283	0.0241	0.615	0.671
400	0.0280	0.0246	0.605	0.679

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04614	0.03478	0.02725	21.67	28.75	36.70
10	0.04456	0.03362	0.02632	22.44	29.74	37.90
Solv.	0.04317	0.03245	.....	23.16	30.81	.....

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0327	0.0276
10	0.0325	0.0277
Solv.	.....	.....

TABLE XIX.

Lithium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	12.16	15.57	.....	66.0	65.8	....
4	14.10	18.07	.....	76.5	76.4	....
10	16.11	20.58	25.54	87.5	87.0	86.9
50	17.38	22.29	27.68	94.4	94.2	94.1
200	18.42	23.66	29.34	100.0	100.0	99.8
400	18.23	23.63	29.40	.....	.....	100.0
K						

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0280	.....	0.341	.....
4	0.0281	.....	0.397	.....
10	0.0277	0.0241	0.447	0.496
50	0.0283	0.0242	0.491	0.539
200	0.0284	0.0240	0.524	0.568
400	0.0296	0.0244	0.540	0.577

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	ϵ 35°	φ15°	φ 25°	φ 35°
2	0.05191	0.03873	0.03019	19.26	25.82	33.12
4	0.04720	0.03571	0.02786	21.19	28.00	35.89
10	0.04460	0.03157	0.02646	22.42	31.68	37.79
Solv.	0.04272	0.03196	0.02503	23.41	31.29	39.95

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0340	0.0283
4	0.0321	0.0282
10	.....	.....
Solv.	0.0337	0.0277

TABLE XX.

Barium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
10	30.58	40.00	50.12	70.3	71.6	70.1
50	38.06	49.43	61.90	87.5	88.5	86.6
200	40.38	52.48	65.93	92.9	93.9	92.2
800	43.45	55.82	70.38	99.9	99.9	98.5
1600	43.48	55.86	71.48	100.0	100.0	100.0
K	1.58×10^{-5}	2.02×10^{-5}	2.45×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
10	0.0308	0.0253	0.942	1.012
50	0.0299	0.0234	1.137	1.157
200	0.0300	0.0256	1.210	1.345
800	0.0285	0.0261	1.237	1.456
1600	0.0285	0.0280	1.238	1.562

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ15°	φ 25°	φ 35°
10	0.04941	0.03702	0.02878	20.24	27.01	34.75
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
10	0.0322	0.0280
Solv.	0.0335	0.0283

TABLE XXI.

Mercuric Chloride in Formamid.

MOLECULAR CONDUCTIVITY.

V	Molecular conductivity 15°	25°	35°
4	0.43	0.59	0.83
10	0.63	0.87	1.27
50	1.09	1.56	2.22
200	1.74	2.53	3.68
400	2.73	4.15	5.82
1000	....	134.49	....
1600	....	101.13	....
3200	....	75.35	....
K	1.30×10^{-5}	1.65×10^{-5}	2.03×10^{-5}

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
4	0.0372	0.0407	0.016	0.024
10	0.0381	0.0460	0.024	0.040
50	0.0431	0.0423	0.047	0.066
200	0.0437	0.0455	0.076	0.115
400	0.0520	0.0402	0.142	0.167

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04688	0.03527	.....	21.33	28.35	.....
10	0.04496	0.03376	.....	22.25	29.62	.....
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TABLE XXII.

Cobalt Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
10	27.11	35.35	44.30	60.9	61.4	60.7
50	34.70	45.01	56.56	78.0	78.1	77.5
200	39.00	50.34	.....	87.7	87.4	....
800	44.48	57.60	72.95	100.0	100.0	100.0
1600	41.83	53.96	68.70			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	Per cent. 25°–35°	Conductivity units 15°–25°	Conductivity units 25°–35°
10	0.0304	0.0253	0.825	0.895
50	0.0297	0.0257	1.031	1.155
200	0.0291	.....	1.134	.....
800	0.0295	0.0266	1.312	1.535
1600	0.0290	0.0273	1.213	1.474

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
10	0.04892	0.03699	0.02867	20.44	27.03	34.88
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
10	0.0322	0.0290
Solv.	0.0335	0.0283

DISCUSSION OF RESULTS.

Tables III to XXII, inclusive, give the molecular conductivity, dissociation, viscosity and fluidity, as well as the temperature coefficients both of conductivity and fluidity for all the salts studied.

In this laboratory, during the past fifteen years, solutions in the following pure solvents have been investigated: Water, methyl and ethyl alcohols, acetone, and glycerol. Among the results of this work in pure solvents are the discovery or confirmation of many relations between the conductivity and viscosity of solutions, the dissociation of the solutes, and the dielectric constant, association factors and viscosities of the solvents.[13] Reference to Table II shows that formamid is a solvent markedly different from any other pure solvent investigated, in regard to the three constants mentioned. The most important result of this investigation is that the evidence it has developed supports and confirms all the relations and conclusions that have been worked out by Jones and his co-workers, from their investigations with other pure solvents. These relations will be discussed in turn.

The Thomson [14]-Nernst [15] theory is that the forces which hold

[13] These results have been tabulated and discussed in Publications of the Carnegie Institute Nos. 170, 180, and 210.

[14] *Phil. Mag.*, 36, 320 (1893).

[15] *Zeit. phys. Chem.*, 13, 531 (1894).

the atoms together are electrical; hence the solvent having the highest dielectric constant has the greatest dissociating power. The dissociating power of solvents is shown in two ways: first, by comparing the percentage dissociation of solutions having the same normality; and, second, by comparing the dilutions at which complete dissociation is reached. Compare Table VII with the following:

Aqueous potassium iodide solution at 25

V			Temperature percentage coefficient, 25°–35°
2	112.8	76.6	1.85
8	120.7	82.0	1.97
2048	147.2	100.0	2.04

Table VII shows that the dissociation of the N/2 solution of potassium iodide in formamid is only 71 per cent. at 25°. From the data we calculate that the viscosity of the N/2 solution is 12.4 per cent. greater than the solvent, while the viscosity of N/2 solution of potassium iodide in water is known to be less than that of the solvent. From a large mass of evidence we know that viscosity is by far the largest factor affecting conductivity in solutions in which dissociation is of the same order of magnitude. The conductivity of the N/2 solution in formamid at 25° is 18.67. We can assume without appreciable error that if the viscosity of the solvent and the N/2 solution were in the same ratio as in the case of the potassium iodide solution in water, the conductivity of the N/2 solution in formamid would be at least 12.4 per cent. larger than the figure given—18.67. Recalculating the dissociation of the potassium iodide-formamid solution on this basis gives 79.4 per cent., compared with 76.6 per cent. for the potassium iodide solution in water. This latter figure would be even less if corrections were made for the fact that the viscosity of an N/2 solution in water is less than that of the solvent, which would be a legitimate correction to make for the purpose of this comparison. Comparing in this way the dissociation of these two N/2 solutions, we find, as would be expected from the Thomson-Nernst theory, *that formamid has the greater dissociating power.*

Complete dissociation of potassium iodide in formamid is found in the N/200 solution, while in water it is not reached till the N/2048 solution. Therefore, in both respects, formamid falls

in line with the Thomson-Nernst theory. This relation is confirmed by every salt studied in this investigation for which data for comparison are available. The rubidium salts show the stronger dissociating power of formamid much more than some others that were studied.

The hypothesis of Dutoit and Aston [16] states that the greater the association factor of the solvent, the greater its dissociating powers. Table I shows the relation of formamid to other pure solvents in regard to association factors. The correction and comparisons made above, with reference to the Thomson-Nernst theory, are equally applicable in connection with the Dutoit and Aston theory. Having these two theories in mind, it is of interest to give here the percentage dissociations of a few salts in ethyl alcohol, for comparison with the data given in Tables VII, VIII, and XIX.

Solutions in Ethyl Alcohol at 25°.

Salt	V for	α
KI	8192	76.7
KCNS	6400	93.8
$LiNO_3$	6400	89.9

The above table was taken from the data of Jones and Kreider. Jones and Mahin showed that complete dissociation of lithium nitrate in acetone is not reached even when V is 100,000. The significance of these figures is apparent if one has in mind the association factors and dielectric constants of formamid, ethyl alcohol, and acetone, given in Table II.

Jones and Veazey's [17] explanation of the decrease in viscosity produced to the greatest extent by cæsium and rubidium salts, and in a less degree by potassium, ammonium, and other salts, all having very large molecular and atomic volumes, has been of special interest in this investigation. They base their hypothesis on the theory of Thorpe and Roger, that viscosity is due to the friction between the surfaces of the molecules. If the particles of the solute are larger than those of the solvent, the frictional surfaces and, consequently, the viscosity will be decreased. If the added particles are smaller than those of the solvent, the vis-

[16] *Compt. Rend.*, **126**, 240 (1897).
[17] *Amer. Chem. Journ.*, **37**, 405 (1907).
Carnegie Institute of Washington, Publication No. **80**, (1907).

cosity will be increased by the addition of the solute. The viscosity of all the concentrated solutions of salts having very large atomic or molecular volumes has been found to be less than the solvent in the case of all pure solvents, except acetone, which have previously been studied. The viscosity of formamid has, on the contrary, been *increased* by every salt used. The complex formamid molecule, $HCONH_2$, and its very large association factor, 6.18, show that its actual molecule is *larger than that of any other pure solvent used in these investigations,* and the increase in viscosity by the salts named above confirms this conclusion. The following comparison strikingly illustrates this relation: A N/2 solution of rubidium iodide in glycerol *decreases* the viscosity of the solvent 13 per cent., while a N/2 solution of the same salt in formamid *increases* the viscosity of the solvent 12.7 per cent. This relation will be referred to again in discussing the results of the work with cæsium nitrate and chloride.

That the percentage temperature coefficients of conductivity increase as the viscosity of the solution increases, is a relation that has been brought out by all the investigations in this laboratory. These coefficients for solution in formamid have the order of magnitude that would be expected from the relation of their viscosities to the viscosities of the same solutions in other solvents. For example, compare the coefficients for solutions of potassium iodide in water, given in the table on page 595, with those for the same salt in formamid in Table VII.

All salts containing water of crystallization were carefully dehydrated at suitable temperatures, just before the solutions were prepared. No thermal measurements were made of the heat of solution, but in the case of sodium iodide, which crystallizes with two molecules of water, a marked rise in temperature was noted when the salt dissolved in formamid, which indicated the formation of a solvate. It is well known that solvated salts give higher temperature percentage coefficients of conductivity than non-solvated, because complexes are usually simplified by rise in temperature. In the present investigation, salts crystallizing with water have given the larger coefficients, indicating the formation of solvates analogous to the formation of solvates by the same salts in water and other solvents. To illustrate this relation, let us compare these coefficients for sodium chromate, crystallizing with ten molecules of water (Table V), and cobalt bromide,

crystallizing with two molecules of water (Table XXII); also compare sodium iodide, crystallizing with two molecules of water (Table IV), with potassium iodide (Table VII). The coefficients for the dilute solutions of sodium chromate are probably not reliable for this comparison, as will be explained under the discussion of this salt.

SODIUM CHROMATE.

Table V gives the results for sodium chromate. They are of the usual order of magnitude, except for the N/1600 solution. At each temperature the increase in conductivity between the N/800 and N/1600 solutions is 59 per cent., which is probably due to chemical action or decomposition, instead of to an increase in ionization. Formic acid is a strong reducing agent. Formamid may be considered as formic acid in which a hydroxyl has been replaced by an amido group. Both the hydroxyl and amido group are basic; therefore, we might expect from this relationship that formamid would be a reducing agent. The reducing action of formamid will also be discussed with the results for mercuric chloride. Sodium chromate is a strong oxidizing agent; hence, it is not surprising that there should be chemical action between these two compounds when the chromate is in a highly ionized condition, as in a dilute solution. The percentage dissociations have not been calculated, because the conditions just referred to introduce an uncertainty regarding them.

MERCURIC CHLORIDE.

The conductivity of aqueous solutions of mercuric chloride is too small to be measured, but in formamid, on account of its greater dissociating power, the conductivity is measurable, and increases as dilution increases in the usual way up to the N/400 solution. The conductivity values for the N/1000, N/1600, and N/3200 solutions clearly result from some decomposition, probably of the solvent. The conductivity of barium chloride at complete dissociation is 55.86 at 25°. The large value, 134.49, for the N/1000 mercuric chloride solution shows that it is not due to dissociation. Assuming that at complete dissociation the conductivity of mercuric chloride would be of the same order of magnitude as of barium chloride, the dissociation of the N/4 solution would be about 1.0 per cent., increasing to about 7.0 per cent. for

the N/400 solution. Silver chloride is precipitated in the N/400 solution by silver nitrate. By standing in the sunlight for a short time, a heavy precipitate of metallic silver is formed, showing again the reducing action of formamid.

To recover the solvent from the mercuric chloride by vacuum distillation required several more distillations than usual. Metallic mercury was found in the receiver after the first distillation, showing again the reducing action of formamid. It is possible that the liberated chlorine formed a salt with the formamid which was easily dissociated, since the conductivity of the first fraction of the distillate was very high, and was lowered only a small amount by successive distillations. Repeated distillation, however, gave the solvent used for the solutions of the cæsium salts.

COBALT BROMIDE.

The green, anhydrous cobalt bromide gives a pink solution in formamid as in water. After the determinations were made, a mixture of solutions was distilled to recover the formamid. The mixture contained mercuric chloride and cobalt bromide. As already stated, the mercuric chloride was reduced to metallic mercury. The dry residue in the distillation flask had the brilliant blue color of anhydrous cobalt chloride, showing that the free chlorine from the mercuric chloride had replaced the bromine in the cobalt bromide.

CÆSIUM NITRATE AND CHLORIDE.

For several years past this laboratory has been unable to obtain any cæsium salts for its investigations in conductivity and viscosity. Recently, some cæsium sulphate was obtained through the coöperation and courtesy of Prof. James Lewis Howe, of Washington and Lee University. The sulphate was converted into the nitrate and chloride, and the conductivity and viscosity of their solutions were determined. The results are recorded in Tables XVII and XVIII.

A survey of the work on the salts of all the alkali metals shows that conductivity values for the cæsium, rubidium, and potassium salts used are approximately the same, and for sodium and lithium are less. The same relation is true of the results obtained in aqueous solutions. Dissociation percentage is of the same order of magnitude for all the salts named. The con-

ductivity results in connection with the dissociation percentage harmonize with the ionic velocities. For cæsium, rubidium, and potassium the relative ionic velocities are 73.6, 73.5, and 70.6, respectively, and for sodium and lithium they are 49.2 and 39.8.

The most striking difference between these metals is shown by the atomic volume curve of Lothar Meyer.[18] This function increases by nearly regular steps from 12 for lithium to 72 for cæsium. In accordance with the theory of Jones and Veazey,[19] to which reference has already been made, the percentage increases in the viscosity of the concentrated solutions over the viscosity of the solvent should be the smallest for cæsium salts, and should increase in the following order: Cæsium, rubidium, potassium, sodium, and lithium. This relation comes out clearly by comparing the viscosity data for cæsium and rubidium salts (Tables XIII to XVIII) with those for sodium and lithium. The salts of rubidium and cæsium increase the viscosity of formamid much less than sodium and lithium salts (Tables III, IV, and XIX). The difference in percentage increase is not as marked as the difference in the atomic volumes of the metal ions. The effect is partially suppressed by other factors. Consider the solution of a binary salt which is 80 per cent. dissociated. Every hundred molecules of the salt gives, in solution, eighty anions, eighty cations and twenty molecules. The eighty cations are only 44.5 per cent. of the number of particles in the solution. It is only this 44.5 per cent. of cations which have the atomic volume relations referred to above. The molecular volumes do not show this relation, and the atomic volumes of the anions are unknown.

SUMMARY OF RESULTS.

The first five of the conclusions drawn below have been developed or confirmed by the investigations in this laboratory with other pure solvents, and have been shown by this investigation to hold true for formamid.

1. The greater the dielectric constant of a solvent the greater its dissociating power.

2. The greater the association factor of a solvent the greater its dissociating power.

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[18] *Lieb. Ann. Suppl.*, 7, 354 (1870).

[19] Carnegie Institute of Washington, Publication No. 80, (1907); *Amer. Chem. Journ.*, 37, 405 (1907).

3. The formation of *solvates* with formamid is indicated by those salts that form hydrates.

4. Solvated salts show larger percentage temperature coefficients of conductivity than non-solvated salts.

5. The order of magnitude of percentage temperature coefficients of conductivity is approximately proportional to the viscosity of the solutions.

6. Formamid is the first of the pure solvents studied with reference to the viscosity of solutions, in which none of the salts used produce negative viscosities. A satisfactory explanation of the above fact is apparent, if the very large association factor of the solvent is considered in connection with the theory of Jones and Veazey.

7. In regard to conductivity, dissociation, and effect on viscosity of solvent, cæsium salts are very closely allied to rubidium salts.

8. Mercuric chloride is more dissociated in formamid than in water.

Johns Hopkins University,
May 15, 1915.

Metropolitan Needs and Sizes of Prime Movers. ANON. (*Electrical World*, vol. 66, No. 15, October 9, 1915.)—With the advent of the 20,000-kilowatt steam turbine many of the problems then confronting large modern generating stations were solved. However, the equipment soon proved to be too small to meet the rapidly advancing loads. The installation of 30,000-kilowatt and 35,000-kilowatt since has made another step forward in meeting pressing metropolitan needs, and now units of 50,000-kilowatt rating are being seriously considered. High economy and reliability are not the only desiderata in increasing the size of prime movers. Labor, real estate, and other considerations depending upon loads, design, and location of plant in a large city are factors almost as important. Recently many of the large lighting companies have acquired huge railway loads, it being generally recognized by railway officials that this is advantageous to them.

In New York City 30,000-kilowatt units are used to handle the elevated-railway and subway demand of the Interborough Rapid Transit Company. Units of 20,000 kilowatts are used by the central stations of New York, Cleveland, Detroit, and Chicago, and 30,000-kilowatt units in New York, Chicago, and Philadelphia. Philadelphia has the distinction of possessing the largest steam turbine thus far installed, a 35,000-kilowatt unit.

Stellite. E. HAYNES. (*Proceedings American Institute of Metals,* September 28 to October 1, 1915.)—The name "Stellite" is applied to an alloy of cobalt and chromium. By the addition of tungsten or molybdenum, or both, very hard alloys are formed, capable of scratching any steel that can be produced suitable for cutting tools for machining iron and steel. The value of the stellite tool lies in its ability to maintain its cutting edge at high speed at temperatures which would cause the failure of any known tools containing a notable quantity of iron. A stellite tool ⅜ inch square by 2½ inches long is reported to have turned off more than 8000 pounds of cast iron before becoming too short for use. Considering only the portion of the tool ground away, it turned off 1000 times its own weight.

A New Method of Making Sulphuric Acid. ANON. (*Commerce Reports,* No. 222, September 12, 1915.)—A new method of manufacturing sulphuric acid, for which advantages are claimed, is suggested in the United States Department of Agriculture Bulletin No. 283, "The Production of Sulphuric Acid and a Proposed New Method of Manufacture." The essential difference of the method from the usual one is that the gases employed are drawn downward through a spiral flue in place of being drawn through lead chambers or intermediate towers. It is asserted that the resistance of gases to the downward pull and the constant change in their course through the spiral tend to mix them very intimately. The fact that the gases constantly impinge on the walls of the spiral flue, which can be cooled by either air or water, makes it practicable to maintain the gases at a temperature most favorable for the efficient yield of sulphuric acid.

The method has been tried only on a laboratory scale, and the bulletin refuses to predict just how efficient the commercial plant would be, but states that all indications are that this method offers promise of being economically successful.

Bibliography of Chemistry of Gas Manufacture. (*United States Bureau of Mines, Technical Paper No. 120.*)—A bibliography of the chemistry of gas manufacture has just been issued by the United States Bureau of Mines. The references in this bibliography have been selected from a much longer list gathered by the Bureau during several years of research work on problems dealing with the chemical behavior of hydrocarbons. No attempt is made to cover every phase of gas manufacture, including the construction and operation of plants, the object being to present a bibliography of carefully-chosen references dealing with the chemistry of gas making and the chemical changes involved in the production of combustible gases.

In view of the fact that there is no such published bibliography, the list, together with its cross-references, is published by the Bureau of Mines in the hope that it will serve as an efficient guide for investigators, chemists and engineers, and for operators of gas plants.

ON THE RETENTION OF ACTIVITY BY UREASE AND BY OXIDASE AFTER EXPOSURE TO THE TEMPERATURE OF LIQUID AIR.

BY

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AND

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ALTHOUGH several investigators have subjected solutions of enzymes to the temperature of liquid air, the time of exposure has rarely exceeded one hour. Pozerski [1] kept pepsin, trypsin, invertase, diastase, and inulinase at that temperature for 45 minutes, rennin for one hour. Chanoz and Doyon [2] held thrombin at that temperature for 13 minutes, rennin for periods of 1, 5, 10, and 30 minutes. Macfadyen [3] subjected zymase to the temperature of liquid air for 20 hours. Each of these enzymes was usually found to retain its full activity after having been exposed to this exceedingly low temperature. The methods used to determine the enzymic activity were, however, qualitative as a rule.

In the present study, the activity of an aqueous solution of urease was quantitatively measured before and after subjecting it to the temperature of liquid air for a period of 100 hours.

The temperature of liquid air lies between the boiling-point of nitrogen and that of oxygen. Fischer and Alt [8] give the boiling-point of liquid nitrogen at a pressure of 760 mm. as 77.33° ± 0.05° absolute or −195.67° C. Travers, Senter, and Jaquerod [9] give the boiling-point of liquid oxygen at a pressure of 760 mm. as 90.10° absolute (−182.90° C.) when determined on the hydrogen scale, 90.20° absolute (−182.80° C.) when determined on the helium scale.

The urease was the commercial article, prepared from the soy bean *Glycine hispida*, and contained five per cent. of potassium phosphate.[4] A solution of 1 gramme of the enzyme to each 10 c.c. of water was used.

The solution of the enzyme was frozen by placing it in a thin-walled glass test-tube, which was then plunged in liquid air contained in a transparent Dewar flask. In order to avoid rupture

of the test-tube by the expansion of the solution in freezing, it was necessary to freeze slowly and to add the enzyme solution in successive increments of 1 c.c. The total volume frozen in the tube was 11 c.c.

The tube and its contents were then transferred to a silvered Dewar bulb, containing liquid air. This bulb was heavily insulated with felt. The level of the liquid air was initially above that of the frozen enzyme solution, and this relation was maintained throughout the 100 hours by addition of liquid air at intervals.

At the end of 100 hours the test-tube and its contents were removed from the Dewar bulb, and the enzyme solution was permitted to thaw at the temperature of the room. The activity was then determined.

In order to measure the activity of the urease, 5 c.c. of the thawed solution were mixed with 25 c.c. of the substrate solution and were then incubated for 15 minutes at 40° C. The substrate [4] contained in 100 c.c.:

4.3 grammes dipotassium phosphate.
3.4 grammes monopotassium phosphate.
6.0 grammes urea.

Several grammes of potassium carbonate and sufficient alcohol to prevent foaming during the aëration were then added, and the ammonia, liberated by the enzyme, was determined by aspiration for one hour, collecting the ammonia in an excess of $\frac{N}{10}$ sulphuric acid, and titrating the excess of acid with $\frac{N}{10}$ sodium hydroxide, using Congo red as the indicator. Five cubic centimetres of the thawed enzyme solution were inactivated by boiling, and were used in a blank experiment. A determination proper and a blank experiment had been carried out on a portion of the original urease solution immediately after its preparation. The quantity of enzyme and of substrate, the period and temperature of incubation, and the mode of estimation of the ammonia formed were exactly as outlined above.

For comparison, a quantitative determination was also made of the activity of another portion of the enzyme solution, after holding in a thermostat at 20° C.—approximately room temperature—for 100 hours. In order to exclude bacterial action, sufficient trikresol had been added to make this a 0.2 per cent. solution

of that bactericide. Graves and Kober [5] have used this strength of trikresol in their recent study of urease. The mode of estimation of the enzymic activity was the same as already described.

The number of cubic centimetres of $\frac{N}{10}$ ammonia found in the corresponding blank has been subtracted from the number found in each determination proper; the remainder, which represents the ammonia liberated by the enzyme from the urea, is given in the table:

	Ammonia liberated by urease, c.c. $\frac{N}{10}$ NH_3	Per cent. of enzymic activity retained
Fresh	49.90	
After 100 hours in liquid air	48.05	96.29
*After 100 hours at 20° C.	22.15	44.39

*Used 0.2 per cent. trikresol as a bactericide.

The tabulated results show that, during prolonged exposure to the temperature of liquid air, urease suffers but a slight loss of its power to hydrolyze urea. The loss of enzymic power was far more pronounced at approximate room temperature, even though the urease was protected by a bactericide.

Oxidase.—So far as the authors know, the resistance of oxidase to the temperature of liquid air has not hitherto been studied.[6] One cubic centimetre of a ¼ per cent. aqueous solution of potato skin oxidase—cresol tryosinase of Chodat [7]—was frozen in the manner described above, and then held in liquid air for 3½ hours. The solution, after having thawed, retained its power to produce a cherry-red color with a 1 per cent. aqueous solution of Witte peptone plus a dilute aqueous paracresol solution.

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[7] Chodat, *Archives des Sciences Physiques et Naturelles*, Serié iv, 1912, xxxiii, 70.
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Special Rowboats for Outboard Motors. ANON. (*Motor Boating*, vol. xvii, No. 3, September, 1915.)—Several years ago a compact gasoline engine power plant was introduced, arranged to be easily attached at the stern of a rowboat and as easily removed. It was designed primarily for existing rowboats, but as its use became widespread it grew apparent that the ordinary rowboat could be improved upon in certain ways, resulting in the production of boats especially designed for use with the outboard motor.

The differences in design of the new rowboat consist chiefly in the use of stronger stern transoms to bear the weight of the attached motor, changes in the hull displacement so that with the motor in place and the operator sitting near it the bow will not be thrown out of the water, and general sturdier construction to meet increased speed and augmented passenger capacity.

It is not to be thought that the old-fashioned rowboat will not prove satisfactory, but there has been a demand by owners of outboard motors for something just a little more suited to their power plants, and so, in the last year or two, nearly a score of boat builders are offering " outboard motor rowboats," as they are called.

Boiler Repair Ships. ANON. (*The* (London) *Times Engineering Supplement*, No. 490, August 27, 1915.)—The employment of welding for repairs to boilers in ships has now become quite common, and special boats are frequently constructed in which all the apparatus for the purpose is fitted.

In some interesting craft of this kind which have recently been put into service in Sweden, Diesel engine sets are installed. A 3-cylinder, 37-h. p. motor running at about 550 r. p. m. is coupled to an air compressor, compressing up to about 100 pounds per square inch, and also a dynamo which provides the current not only for welding but also for propelling the boat by means of an electric motor placed in the stern. The compressed air is used for the pneumatic tools required in carrying out the repairs.

Properties and Uses of Military Explosives. L. CRESAP. (*The Iron Age*, vol. 96, No. 14, September 30, 1915.)—From a military point of view there are two distinct classes of explosives—slow and fast. The slow explosives, whose rate of decomposition or burning can be controlled, are used as propellants for projectiles in guns. The fast explosives are those in which the rate of burning is not controlled and explode or burn with the greatest possible rapidity. Such explosions are generally called detonations and find application in shells, mines, torpedoes, etc.

The interval of time occupied by these classes of explosives is a distinguishing feature. The explosion of a slow explosive occurs in a period greater than one-fiftieth of a second, while in a high explosive measurements have shown some detonations to spread at a rate of 10,000 feet per second.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A NEW RELATION FROM PLANCK'S LAW.

By Paul D. Foote.

[ABSTRACT]

NUMEROUS displacement laws may be derived from the Planck relation representing the spectral distribution of the energy radiated by a black body. In the present paper a new displacement law is derived which states that the product of the absolute temperature θ and the λ – component of the centre of gravity of the spectral energy curve λ_c is a constant, as follows:

$$\theta\lambda_c = 0.37021\ C_2$$

where C_2 is the characteristic constant of the Planck equation.

THE MICROSTRUCTURAL CHANGES ACCOMPANYING THE ANNEALING OF BRONZE (Cu88, Sn10, Zn2).

By Henry S. Rawdon,
Assistant Physicist.

THERE is a common misunderstanding among metal workers in regard to the "grain refining" or recrystallization of brass and bronze upon annealing, many regarding the change in the same light as the "grain refining" of steel. This study shows the modifications which occur in the microstructure and the temperatures at which such changes are completed. Zinc bronze, of the composition indicated above, was used as a type, because of its commercial importance and also to supplement the other work on this alloy which has been carried out by the Bureau of Standards.

After casting, the alloy exhibits a complex structure consisting of a dendritic matrix consisting of a solid solution of tin (and zinc) in copper in which are embedded numerous particles of a hard and brittle eutectoid. Upon annealing, the alloy is first rendered homogeneous by the absorption of the eutectoid by the matrix and the disappearance of the dendrites in this same matrix. If the alloy has suffered no deformation previous to annealing, no other changes are observed; the crystal or grain size remains un-

* Communicated by the Director.

changed. The characteristic polyhedral twinned crystals seen in annealed brass and bronze, rich in copper, are obtained only after the structure is distorted previous to heating. Samples which have been cooled in a very drastic manner, thus inducing severe internal strains, behave similarly upon annealing to those which have been mechanically deformed.

The samples used were cylinders, the surface layer of which has been distorted by machining in the lathe. These were then annealed for periods of one, two, four, and eight hours at 400°, 600°, and 800° C. The constancy of the thickness of the recrystallized layer (different for different temperatures), after different annealing periods at the same temperature, is very striking. Though the crystals in this layer of recrystallized metal increase in size, there is no appreciable increase in thickness, thus substantiating Tammann's theory of recrystallization of "cold-worked" metals upon heating.

COMPRESSIVE STRENGTH OF PORTLAND CEMENT MORTARS AND CONCRETES.*

By R. J. Wig, G. M. Williams, and E. R. Gates.

[ABSTRACT]

CONCRETE differs from most structural materials in that it is not manufactured at a mill or plant according to chemical formula, under the observation of skilled specialists, subject to rigid inspection and test and such control as to produce a uniformly homogeneous product; nor is the process of manufacture completed in a few hours or days, as in the case of steel products. Furthermore, concrete is made from materials obtained from many sources, differing widely in characteristics which affect its quality. The proportions of the ingredients, the amount of water used in mixing, the thoroughness of mixing, the manner of placing, the atmospheric temperature and humidity, exposure to sun, rain, and wind, immersion in fresh water or sea-water, or other natural solutions, all affect the quality of concrete.

This paper is a collation and study of about 20,000 tests of mortars and concretes which have been made in connection with the routine and investigative work of the Bureau of Standards and the Structural Material Laboratories of the United States Geo-

* Technologic Paper No. 58.

logical Survey which were transferred to the Bureau of Standards in 1910. Tests were made of about 150 different aggregates, consisting of limestones, granites, gravels, trap rocks, and cinders. Studies have been made to determine the effect of the several variables enumerated above, and a summary of the results and the conclusions are given below.

SUMMARY.

Portland Cement Mortar Mixtures.—Sands as a type of fine aggregates cannot be said to be superior to limestone screenings.

The proper gradation of the fine aggregate for maximum strength in mortar appears to vary with the material.

The results of the tests of the mortars included in this paper would indicate that for most materials the highest strengths are obtainable with those having a gradation of particles approaching a straight line. There are materials, however, which have a gradation varying widely from a straight line which give high strength in mortars.

The quality of a sand cannot be judged from its gradation alone. Any limitation arbitrarily placed upon the proportions of the particles of various sizes will probably eliminate some very satisfactory materials.

No fine aggregate should be rejected because of its "silt" content determined by washing or assuming the material passing the No. 200 sieve as silt, as it may be advantageous even in relatively large quantities or detrimental in small quantities, depending upon its form and distribution. Mortars made from sands having rounded grains have equal strength with mortars made from sands having sharp grains.

The only satisfactory method of determining the value of a fine aggregate in mortar mixtures is to test it in the mixture in the same proportion to be used, exposed to the same conditions as in the proposed structure.

Common usage has demonstrated that certain sands are satisfactory, and therefore no tests of these materials are necessary excepting to identify them.

The relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the concrete aggregate.

Portland Cement Concrete Mixtures.—No type of gravel or

stone aggregate can be said to be generally superior to any other type used as coarse aggregate in concrete mixtures. Certain limestones are superior to certain gravels, and some gravels are better than other limestones. The range of qualities in any of these types is very great, and the strengths of concretes made up of several materials of the same type may vary as much as several hundred per cent., with all other controllable factors uniform.

Relation of Workmanship to Compressive Strength.—Undoubtedly greater uniformity is generally obtained by machine mixing than by hand mixing. The method of mixing is of little importance so long as it results in a homogeneous mass. Using proper methods and with the expenditure of sufficient labor, results indicate that as good concrete can be obtained by hand mixing as by machine mixing, although it probably would not be economical.

With all other factors constant, the results included in this paper show that differences in manipulation of the mixture by the workmen of several experienced concrete contractors may cause a maximum average variation in the compressive strength of the resulting concrete of 70 per cent. or more.

Relation of Consistency of Mixture to Compressive Strength.—The quantity of water added to the mixture in preparing concrete affects materially the compressive strength at all ages With the proper quantity of water the strength may be several hundred per cent. greater than that obtained with a large excess of water.

The most satisfactory consistency from the standpoint of strength and durability is a quaking mixture, and the error should be on the side of using too little rather than too much water, providing it is properly spaded or worked into place in the forms. This statement does not apply to the very dry mixtures used in the manufacture of concrete blocks, etc. In the case of these products the mixture should contain the maximum quantity of water which will permit of the immediate removal of the moulds. This mixture has less water than the quaking consistency described above.

Relation of Density to Compressive Strength.—With the same aggregates and the same proportion of cement to total volume of aggregate the mixture having the greatest density will have a high, and usually the highest, compressive strength.

Density is no criterion of compressive strength of two mix-

tures of an aggregate if the ratio of cement to total volume of aggregate is not the same.

Density is no criterion of compressive strength of two mixtures of the same proportions of cement to total aggregate if different aggregates are used, although where the aggregates are quite similar they may be comparable.

Effect of Various Exposures on Compressive Strength.—The character of the exposure of the concrete after moulding materially affects its compressive strength. If the original water is permitted to evaporate from the concrete and all water is subsequently excluded, the compressive strength may be reduced 40 per cent. or more. Concrete should preferably be kept wet for several days or weeks after it is deposited if the maximum strength is to be attained.

Effect of Exposure to Steam on Compressive Strength.—Steam greatly accelerates the hardening process, and will increase the strength of concrete only a few days old by several hundred per cent., depending upon temperature and duration of exposure.

Relation of Gradation of Aggregate to Compressive Strength.—There is no definite relation between the gradation of the aggregate and the compressive strength which is applicable to any considerable number of different aggregates.

The gradation curve for maximum compressive strength, usually the same as for maximum density, differs for each aggregate.

The so-called "maximum density curve," which is a combination of the straight line and ellipse, does not represent the curve for maximum density excepting for the particular materials used in the tests from which it was derived, or very similar materials.

No equation for a gradation curve, which can be applied to a number of different aggregates, can be prepared from the results included in this paper.

Excessive fineness does not necessarily result in a totally unsatisfactory sand for concrete. A sea-shore sand having 99 per cent. passing a 50 mesh sieve when mixed with a good aggregate and cement was found to give a satisfactory concrete.

CONCLUSIONS.

1. No standard of compressive strength can be assumed or guaranteed for concrete of any particular proportions made with any aggregate unless all the factors entering into its fabrication are controlled.

2. A concrete having a desired compressive strength is not necessarily guaranteed by a specification requiring only the use of certain types of materials in stated proportions. Only a fractional part of the desired strength may be obtained unless other factors are controlled.

3. The compressive strength of a concrete is just as much dependent upon other factors, such as careful workmanship and the use of the proper quantity of water in mixing the concrete, as it is upon the use of the proper quantity of cement.

4. The compressive strength of concrete may be greatly reduced by the use of an excess of water in mixing to a fractional part of that which it should attain with the same materials. Too much emphasis cannot be placed upon the injurious effect of the use of excessive quantities of water in mixing the concrete.

5. The compressive strength of concrete may be greatly reduced if after fabrication it is exposed to the sun and wind or in any relatively dry atmosphere in which it loses its moisture rapidly even though suitable materials were used and proper method of fabrication employed.

6. The relative compressive strength of concretes to be obtained from any given materials can be determined only by an actual test of those materials combined in a concrete.

7. Contrary to general practice and opinion, the relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the coarse aggregate.

8. Contrary to general practice and opinion, the relative value of several coarse aggregates to be used in concrete cannot be determined by testing them with a given sand in one arbitrarily selected proportion. They should be tested in such combination with the fine aggregates as will give maximum density, assuming the same ratio of cement to total combined aggregate in all cases.

9. No type of aggregate such as granite, gravel, or limestone can be said to be generally superior to all other types. There are good and poor aggregates of each type.

10. By proper attention to methods of fabrication and curing, aggregates which appear inferior and may be available at the site of the work may give as high compressive strength in concrete as the best selected materials brought from a distance, when the latter are carelessly or improperly used.

11. Density is a good measure of the relative compressive strength of several different mixtures of the same aggregates with the same proportion of cement to total aggregate. The mixture having the highest density need not necessarily have the maximum strength, but it will have a relatively high strength.

12. Two concretes having the same density but composed of different aggregates may have widely different compressive strengths.

13. There is no definite relation between the gradation of the aggregates and the compressive strength of the concrete which is applicable to any considerable number of different aggregates.

14. The gradation curve for maximum compressive strength, which is usually the same as for the maximum density, differs for each aggregate.

15. With the relative volumes of fine and coarse aggregate fixed the compressive strength of a concrete increases directly, although not in the same proportion as the cement content. An increase in the ratio of cement to total fine and coarse aggregates when the relative proportions of the latter are not fixed does not necessarily result in an increase in strength, but may give even a lower strength.

16. The compressive strength of concrete composed of given materials, combined in definite proportions and fabricated and exposed under given conditions, can be determined only by testing the concrete actually prepared and treated in the prescribed manner.

STANDARD TEST SPECIMEN OF ZINC BRONZE (Cu_{88}, Sn_{10}, Zn_2). PART II—MICROSTRUCTURE.

By Henry S. Rawdon,

Assistant Physicist.

[ABSTRACT]

THE work constitutes a part of the study of the properties and structure of standard alloys undertaken by the Bureau of Standards at the request of the American Institute of Metals.

This study of the microstructure supplements the determination of the physical properties and endeavors to explain some of the differences observed.

Simple reference is made to the equilibrium diagrams of copper and tin and copper and zinc in order to explain the struc-

ture to be expected in such alloys. The examination of a large series of specimens cast by the different methods chosen (Part I) shows that the structure is affected only indirectly by the rate of cooling, inclusions of foreign materials, etc. The characteristic appearance of tensile bars of the alloy after breaking is explained and the relation to the microstructure of the cast alloy shown.

Of all the microstructural features affecting the properties of the alloy, the presence of films and pits of oxide far outranks the others in the bad effects produced. The use of zinc alone as a deoxidizer appears not to be sufficient and dependable. The oxides occur both in the form of pits and thin branching films, the second form being the one especially pronounced in its effects. The changes in the microstructure of the alloy upon heat treatment are explained and illustrated, and the possible use of heat treatment to improve the properties of badly-oxidized metal is suggested.

A series of photomicrographs is included to illustrate the structure of the alloy and relation of the microstructure to other physical properties. The article has been made as non-technical as possible in order to appeal to a wide range of readers, including manufacturers and foundry men, as well as buyers and users of the alloy.

EARTH RESISTANCE AND ITS RELATION TO THE ELECTROLYSIS OF UNDERGROUND STRUCTURES.

By Burton McCollum and K. H. Logan.

THIS paper presents some of the results of the laboratory and field work of the Bureau of Standards carried on in connection with the study of electrolysis and its mitigation. The resistance of the soil in which metallic structures are buried is shown to be of much importance with respect to electrolysis of these structures. Three methods of measuring the specific resistance of the soil, two of which do not require the removal of the soil from its original position, are described. Results of soil-resistance measurements by each method are compared, and it is shown that any of the described methods is satisfactory for practical purposes, although each has advantages over the others under certain conditions.

The results of a large number of measurements of resistance of soil samples from widely-separated points in the United States have been tabulated. These data show great variations in soil resistance and indicate the desirability of a study of local soil conditions in connection with any complete electrolysis survey. The majority of soils tested show resistivities of between one thousand and five thousand ohms per centimetre cube.

A number of factors have been found to influence the resistivity of the soil. Increasing the pressure on a sample of soil under test tends to increase the conductance of the sample slightly, especially if the original pressure is low. Increase in moisture increases the conductance of the soil if it is not saturated with water. The amount and kind of soluble material in the soil affects its resistance. The resistance of soil is found to increase as its temperature falls, especially when the freezing-point of water is reached. The flow of current through the soil has been found to produce an apparent temporary increase in soil resistance in the neighborhood of the electrodes.

The relation of soil resistance to electrolysis is considered from the standpoint of leakage from street railway lines using the track as a return current. The importance of good rail bonding and of well-drained roadbed is pointed out.

The relations of the various factors affecting leakage resistance (namely, character of the soil, pressure, moisture, freezing and polarization, and surface films) to the electrolysis problem are described, and it is shown that a knowledge of the resistivity of the soil is of importance in estimating the danger indicated by potential difference and potential gradient measurements. It is also shown that the moisture and temperature of the soil materially affect the amount of current escaping from a grounded track used as a return circuit and that these factors must be given due consideration in the interpretation of data obtained during an electrolysis survey.

FOREIGN SPECIFICATIONS FOR RAILWAY MATERIAL.*

The Bureau of Standards, in connection with its investigation of failures of railway material, has obtained, through the courtesy of the State Department and its consular service, the specifications

* To be published as a Circular of the Bureau of Standards, 1915.

for railway material—rails, wheels, axles, and tires—of the State railways of Germany, Austria, Italy, Belgium, and Sweden, as well as some of those of the railways of Great Britain, France, and Holland. The data available concerning accident statistics and derailments, as well as those bearing on the types and weights of railway equipment—rolling-stock and rails—have been also obtained in the same manner.

These specifications, in so far as they concern rails, axles, wheels, and tires, are given practically in full as an appendix to a forthcoming Bureau Circular. The body of the circular contains a digest and discussion of the accident and derailment statistics, the data on railway equipment, and of the specifications themselves.

There appear to be no foreign statistics available concerning the removal for defects of such railway material as rails, wheels, and axles such as in the United States, but the derailment statistics of the foreign countries show in general a much smaller proportion of derailments due to such defects than is found in the United States.

A few of the many points brought out by a survey of these railway specifications may be mentioned here.

Foreign rails, wheels, and axles are relatively heavier for the traffic which they bear than those in the United States, and that the specifications and tests prescribed for the same are generally very stringent. In particular, drop and impact tests are almost always applied to all such types of railway material, and often this test is at the same time a fatigue or endurance test, which is known to be a very severe test of the quality and toughness of a material.

The chilled cast-iron car wheel is not used a great deal abroad, and hence is hardly mentioned in the specifications. Its place is taken by built-up wheels, consisting of wheel centre and tire, or by spoked wheels. These are made of wrought iron or of steel, forged or cast.

The practice is generally adhered to abroad of requiring a manufacturer's guarantee for such material. Rails, for example, are sometimes guaranteed for from five to six years.

NOTES FROM NELA RESEARCH LABORATORY.*

THE RELATION BETWEEN SPECTRAL COLOR AND STIMULATION IN THE LOWER ORGANISMS.

By S. O. Mast.

It is well known that many of the simplest organisms respond very definitely to light. Some orient and travel fairly directly toward the light, others away from the light, while still others go toward it under some conditions and away from it under others.

In a field of light consisting of two horizontal beams crossing at right angles these organisms proceed toward or from a point situated between the two beams. The location of this point depends upon the relative effective luminous flux illumination received by the organisms from these beams. If it is the same in quality and intensity, so that the stimulation is the same, the point lies approximately half way between them.[1] Consequently whenever the organisms proceed toward or from a point thus located it may be concluded that the stimulating effect of the light in the beams is equal, no matter how it may differ, either in intensity or in quality.[2] It is therefore obvious that if the light in one beam is kept constant in quality (white, for example), while that in the other is changed in color, the relative stimulating efficiency of the different colors can be ascertained. To do this, all that is necessary is to vary the luminous intensity of the white light for each change in the colored light, until, in each case, the organisms proceed on the same path. The stimulating effect of the different colors will then be directly proportional to the various luminous intensities of the white light required to make the organisms under each of the different conditions proceed in the same

* Communicated by the Director.

[1] Details as to the process of orientation in these organisms may be found in my book on "Light and the Behavior of Organisms," John Wiley & Sons, New York, 1911.

[2] This is literally true for only a few organisms, but the principle as applied holds for all, as will be demonstrated in a more comprehensive paper to be published elsewhere.

direction; *e.g.*, if for green, it requires twice the intensity of light from the white source to make the creatures take a given course as it does for yellow; then the stimulating effect of the green is twice as great as that of the yellow. To ascertain the relative efficiency in terms of wave-lengths and energy it is only necessary to use a spectrum having a known distribution of energy, and to make corrections in accord with this distribution.

In the experiments referred to below, two gas-filled, street-series, tungsten lamps with coiled filaments were used in series to produce two beams of light. One of these beams passed through a Hilger constant deviation spectrometer, and the other through a Brodhun rotating sector. The whole apparatus was so arranged that the two beams of light crossed at right angles in the field of observation. For every color tested the intensity of the illumination in the beam of white light was adjusted by varying the opening in the sector until the course of the organisms bisected the angle between the two beams of light. In nearly all cases the successive regions selected in the spectrum differed by 10 $\mu\mu$.

In this way the relative stimulating effect for the different regions of the spectrum was ascertained in fifteen different species, as follows: *Chlamydomonas, Trachelomonas,* and *Phacus,* each one species; *Euglena,* five species; *Pandorina, Eudorina, Gonium,* and *Spondylomorum,* each one species; earthworms, *Arenicola* (larvæ), and blowfly (larvæ), each one species All but the last three are green, microscopic organisms, relatively very simple in structure.

The results obtained will be stated in terms of relative stimulative effects of the different regions of the spectrum tested, without corrections for the difference in the energy of these regions. They are, however, of such a nature that the corrections mentioned will not result in marked alterations. These corrections will appear in a subsequent paper.

For all but one of the microscopic organisms the results fall into two groups. In the one group the region of stimulation begins in the blue near the violet, between 430 and 440 $\mu\mu$. From here toward the red end of the spectrum the stimulating efficiency rises, at first slowly and then rapidly, to a maximum in the green near the yellow, between 530 and 540 $\mu\mu$; then it falls, at first rapidly and later more and more slowly, ending in the red at

about 640 $\mu\mu$. In the other group the region of stimulation begins in the violet between 420 and 430 $\mu\mu$, only a short distance from the place where it begins in the first group. From here the efficiency rises very rapidly, reaching a maximum in the blue between 480 and 490 $\mu\mu$. It then falls rapidly, and ends in the green in the neighborhood of 520 $\mu\mu$. Three of the microscopic forms, *Pandorina, Eudorina,* and *Spondylomorum,* belong to the first group, the rest to the second. To this group belong also *Arenicola* larvæ and the earthworms. For the remaining microscopic form (*Chlamydomonas*) the maximum is in the green very near 510 $\mu\mu$; and for the blowfly larvæ it is approximately at 520 $\mu\mu$. The distribution in the spectrum, of stimulating efficiency is, for this creature, essentially the same as the distribution of brightness for totally color-blind persons.

These results show that stimulation in all of the organisms studied depends upon the wave-length of the light; that the stimulating efficiency is very much higher in certain regions of the spectrum than in others; but that the distribution of this in the spectrum differs greatly in certain organisms that are closely related in structure (*e.g., Pandorina* and *Gonium*), while it is essentially the same in others that are very different in structure (*e.g., Euglena* and earthworms). A more extensive study of this subject ought to lead to an insight into the chemical and physical phenomena that are associated with the reactions in these organisms.

TEMPERATURE AND BLACKENING EFFECTS IN HELICAL TUNGSTEN FILAMENTS.

By Benj. E. Shackelford,
(Charles P. Brush Research Fellow).

THE inside of glowing helical tungsten filaments is very much brighter than the outside. *A priori,* this may be due to internal reflections or to the inside being at a higher temperature than the outside. Coblentz [1] concluded that the major portion of the brightness difference was due to temperature difference between the two surfaces, aside from that due to inability to focus accurately on the edges of the filaments. According to Wodthing's [2]

[1] *Electrical World,* vol. 64, p. 1048.
[2] *Physical Review,* December, 1914.

data on conductivity of tungsten at high temperatures, the maximum allowable difference in temperature between the outside and the inside of the filaments used is usually of the order of 1°, considering the limiting case of a cylinder. This means a difference in brightness of 0.5 per cent., whereas differences of the order of 100 per cent. are observed. The object of the present investigation, therefore, was to determine the causes of the difference in brightness of the two surfaces.

By means of a Holborn-Kurlbaum optical pyrometer brightness readings were taken on the outside and on the brightest portions of the inside of the filaments, excluding the edges because of the difficulty mentioned above and because of the deviation from the cosine law. Five gas-filled lamps were used containing helical filaments of the same size wire wound on the same mandril, but with different pitches, ranging from 1.35 to 3 times the diameter of the wire. In each case on going from the outside of the coil to the inside the red ($\lambda = 0.66\mu$ approximately) brightness increased relatively more than did the blue ($\lambda = 0.46\mu$ approximately); at a red black body temperature of 2250° K. this relative increase was 5 to 10 per cent. more, depending on the pitch. This shows that at least the greater part of the increase in brightness is due to internal reflections and not to the temperature being greater on the inside. If it were a temperature effect in the main, the radiation from the inside would be relatively stronger in the blue. In justification of the above method and conclusion it was found that by plotting the outside-inside brightness ratios against pitch a straight line was obtained. Extrapolating backward to pitch unity, which corresponds to a closed cylinder, it was found that the value of the ratio at 2250° K. was 0.442 for red glass, which agrees very closely with Worthing's value (unpublished) of the emissivity found by an entirely different method. The ratio for blue glass was 0.461. At 1875° K. the brightness ratios were greater, giving a higher value for the emissivity.

Using two templates cut to transmit only the inside and outside radiation respectively when the image of the filament was projected on them, one of the lamps was color-matched against a second helical filament. To match the outside, 0.05 per cent. greater current was necessary than to match the total radiation, and 2 per cent. less was required to match the inside, again showing that the inside is relatively redder than the outside, and that

the larger part of the brightness difference is due to blackening.

A piece of 20-mil wire was flattened to 10 mils, after which it was polished and mounted as a helical filament and operated at 1800° K. Setting now on the darkest portions of the inside, there was only a 2 per cent. greater brightness on the inside than the outside, which means not more than 4° difference in temperature, assuming that to be the sole cause of the difference. Since the surface was not an optical one and some blackening still remained, the actual difference must have been less than this.

To summarize: The data show that the interior of the helical filament has a maximum brightness of the order of twice that of the exterior; that the inside is redder, and that the increased brightness in the main is due to internal reflections; that the temperature difference between the outside and inside of a 10-mil coiled filament is not greater than 4°; also a value of 0.442 is found for the red and 0.461 for the blue emissivity at 2250° K.

It is intended to continue the investigation by means of resistance measurements and by means of brightness measurements on a more perfectly polished flattened filament.

A Direct Reading Analytical Balance. ANON. (*Scientific American*, vol. cxiii, No. 15, October 9, 1915.)—In the present innovation in analytical balances, due to the efforts of Christian Baker, of New York, the weighing is accomplished by a small platinum or gold chain suspended at one end from an adjustable screw fitted to the beam of the balance, and at the other to a hook held by a sliding block. The block, which is marked with a vernier scale reading to one-tenth of a milligramme, is moved along its supporting scale by a vertical spiral drive in the rear, which in turn is rotated by a thumb-screw through bevel gears.

To operate the new balance it is only necessary to rotate the thumb-screw controlling the block so as to cause the leg of the chain hanging from the beam to be lengthened or shortened, adding more or less weight until balance obtains. The window of the balance is closed after the object to be weighed has been placed on the pan, and is left closed during the entire operation. The altering of the chain weight can take place while the beam is swinging, so that neither the pans nor the beam need be rested at any time during the weighing operation, resulting in a great saving of time. The range of the chain weight is considerable: in one of the most popular of these analytical balances it will weigh from one-tenth milligramme to 50 milligrammes. By using a lighter or heavier chain, the graduated scale can be calibrated for finer or coarser weighing.

Artificial Illuminants for Use in Practical Photography-cinematograph Work. C. E. K. MEES. (*Proceedings of the Illuminating Engineering Society,* September 20 to 23, 1915.)—In moving-picture studios a considerable amount of light is necessary, owing to the speed at which the pictures are taken, the exposure being only 1/40 of a second with an aperature of about F/8. The average stage, including an area of perhaps 240 square feet, requires about 60 kilowatts of illumination, and a typical arrangement of lights will consist of 40 to 50 kilowatts expended in mercury-vapor lamps or quartz arcs arranged about 12 or 15 feet above, as a roof to the stage, and down one side to a distance of about 3 feet from the floor, and about 12 kilowatts used in some form of arc, conveniently a flame arc about 10 feet in front of the stage and the same distance from the floor. Such an arrangement is typical of many of the stages used by the large producers of moving pictures in this country, and the importance of artificial illumination in this work can be realized when it is understood that many producers will have six such stages working at one time.

Concerning Aluminum Pistons. ANON. (*The Horseless Age,* vol. xxxvi, No. 9, October, 1915.)—It is sometimes argued that, since aluminum has a very much higher heat conductivity than cast iron, an aluminum piston will not get nearly as hot as a cast-iron piston under similar service, and that consequently, although the coefficient of expansion of aluminum is much greater than that of cast iron, not much more clearance between piston and cylinder need be allowed with aluminum pistons than with the old kind. Extended experience, however, shows that this theory is entirely wrong. It does not seem logical that an increase in the heat conductivity of the piston material should make any important difference in its temperature, because any slight reduction of the temperature of the piston head would result in a corresponding increase in the temperature difference between the burning charge and the piston and in greater heat absorption by the piston. Moreover, the dissipation of the heat absorbed by the piston depends much more on the low conductivity of the oil film separating piston and cylinder wall than upon the conductivity of the piston material. Hence it seems reasonable to suppose that the working temperature of the aluminum piston will be substantially the same as that of a cast-iron piston, and that the clearance allowances must be nearly in proportion to the coefficients of expansion of the two metals, not absolutely, because the piston must not become an absolute fit in the cylinder at working temperature, as then there would be no room left for the oil.

One objection sometimes raised against aluminum alloy pistons is that the rings are harder than the metal of the grooves in which they fit, and that consequently the grooves soon wear. Whatever the explanation may be, experience here again is said to show that the rings wear before the groove.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, October 20, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 20, 1915.

VICE-PRESIDENT JAMES M. DODGE *in the Chair.*

Additions to membership since last report, 14.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

A communication from the Alumni Association was read advising the Institute of the election of Mr. Edward V. McCaffrey to the Board of Managers as the representative of the Association for a period of three years, beginning January, 1916.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, introduced Mr. John C. Wahl, of Chicago, Ill., inventor of the Wahl Calculating Attachment for Typewriters, who had recently been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, on the recommendation of The Franklin Institute, for his invention, and Mr. George W. Dickerman, representing the manufacturers of this device, to whom had been awarded the Edward Longstreth Medal of Merit for the methods and means of its commercial production, and described briefly the invention of Mr. Wahl. The medals were presented to Messrs. Wahl and Dickerman by the President.

Dr. Heinrich O. Hofman, Professor of Metallurgy, Massachusetts Institute of Technology, presented a communication, entitled "Recent Progress in the Metallurgy of Copper." The speaker discussed the great changes which have taken place in this country during the last ten years in the treatment of sulphide copper ore and the fire-refining of copper. In blast-furnace practice the former roasting and reduction process has been almost wholly replaced by some form of pyritic smelting. Smelting in the reverberatory furnace, which was of secondary importance, has been so improved that it is competing to-day with blast-furnace work. In bringing forward copper matte to metallic copper the reverberatory furnace has become obsolete; the pneumatic process of Manhès, which caused this radical change, uses an acid-lined vessel; this has been superseded by the neutral or basic lining. While important progress has been made in the refining of copper, the improvements in the methods are not so radical as those in the treatment of ores. The subject was illustrated by specimens and lantern slides.

After brief discussion the thanks of the meeting were extended to Dr. Hofman by a rising vote.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 6, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 6, 1915.

MR. G. H. CLAMER *in the Chair.*

The following report was presented for first reading:

No. 2617.—Permutit.

The following report was referred back to the subcommittee for reconsideration:

No. 2636.—Lenker's L-E-Vation Rod.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, October 7, 1915, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. Two hundred and fifteen members and visitors were present. The minutes of the previous meeting were approved as read.

Benjamin T. Brooks, Ph.D., of the Mellon Institute of Industrial Research, University of Pittsburgh, delivered a lecture on "The Decomposition of Petroleum Hydrocarbons by Heat and its Application to the Motor Fuel Problem." Brief consideration was given to the relative importance of gasoline substitutes. The decomposition of complex petroleum hydrocarbons by heat, the effect of heat and pressure upon unsaturated hydrocarbons, the use of catalysts in the preparation of gasoline, and the effect of various factors in the deterioration of gasoline were discussed. Special reference was made to methods which have been proved capable of successful large-scale operation. The lecture was illustrated with lantern slides and experiments. After a discussion, a vote of thanks was extended to the speaker and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, October 14, 1915, at 8 o'clock P.M., with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Dr. Ulric Dahlgren, Professor of Biology in Princeton University, delivered an address on "Production of Electricity by Animals." The general presence of minute electric discharges in all vital functions of proto-

plasm was discussed. The species of fish which contain special electric organs were enumerated; and the macroscopic and microscopic structure of these organs and their operating nerve apparatus were described. The development of the electric organs from striated muscle was traced, and their physiology and uses were reviewed. The lecture was illustrated with lantern slides and with specimens of fish. The meeting extended a vote of thanks to Dr. Dahlgren, and then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MINUTE OF THE BOARD OF MANAGERS ON THE DEATH OF JOHN T. MORRIS.

(*Meeting of October 13, 1915.*)

John Thompson Morris, President of the Board of Trustees of The Franklin Institute, and for many years its friend and benefactor, died on August 15, 1915.

The members of the Board of Managers unite with the remaining members of the Board of Trustees in expressing their sense of the deep loss which the Institute has thus suffered, and their gratitude for the devotion which Mr. Morris gave to its interests.

He became a life member of The Franklin Institute in 1880, and when the Board of Trustees was created in 1888 he was appointed to be one of its original members. He was elected president of the Board of Trustees on March 20, 1905, and served in that capacity until the time of his death, always watchful of the trust committed to his hands, and zealous towards ensuring its fulfilment. No detail was so small as to be ignored by him, and no trouble too great to be met by his painstaking care.

In addition to the services thus contributed, Mr. Morris gave to the Institute the sum of $5000, to be employed as a Library Fund, the income to be devoted to the purchase of books on mechanical subjects, this gift being a memorial to his brother, James T. Morris.

Apart, however, from the material side of his connection with the Institute, Mr. Morris brought to its meetings and councils sympathy, intelligence, and brightness.

Thoroughly educated at the start of his career, and trained in experience of men and affairs by his business life, his release from the more arduous duties of business enabled him to expand his knowledge by wide travel and to gratify to the utmost his interest in art.

Those who were privileged to enjoy his personal friendship and share in his hospitality will long remember the keen pleasure which he took in literature, music and the fine arts, and the quiet dignity of his home life, surrounded by the carefully-selected acquisitions of his artistic tastes.

In his later years his interest turned especially towards trees and flowers, but notwithstanding his intimacy with the science that relates to these subjects, one could not fail to observe that his real motive was the love of a tender and gentle nature for the spirit of the woods and of the garden.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, October 13, 1915.)

RESIDENT.

MR. CARL P. BIRKINBINE, Parkway Building, Philadelphia, Pa.
DR. JACOB S. GOLDBAUM, 212 West Winona Avenue, Norwood Station, Pa.
MR. J. ROGERS HOLCOMB, 29 West Tulpehocken Street, Germantown, Philadelphia, Pa.

NON-RESIDENT.

MR. E. Z. CROW, care of American Trust and Savings Bank, Birmingham, Ala.
MR. LEONARD KEBLER, care of Ward Leonard Electric Company, Bronxville, N. Y.
MR. JAMES LYMAN, 1412 Edison Building, Chicago, Ill.

LIFE.

MR. THOMAS W. ELKINTON, care of Philadelphia Quartz Company, 121 South Third Street, Philadelphia, Pa.

ASSOCIATE.

MR. FREDERICK DENIG, 2244 Thirteenth Street, Troy, N. Y.

CHANGES OF ADDRESS.

PROF. JAMES BARNES, Bryn Mawr College, Bryn Mawr, Pa.
MR. HERBERT S. BERLINER, Box 5, St. Henry, Montreal, Quebec.
MR. GIDEON BOERICKE, Wynnewood, Pa.
MR. WILLIAM C. CARNELL, 1108 South Forty-sixth Street, Philadelphia, Pa.
MR. EDWARD L. COSTER, Katonah, N. Y.
MR. FRANCIS X. DAILY, 116 Walnut Avenue, Ardmore, Pa.
MR. FREDERIC A. DELANO, 294 Treasury Building, Washington, D. C.
MR. PAUL DIDIER, Conestoga Building, Wood and Water Streets, Pittsburgh, Pa.
MR. JOHN URI LLOYD, Clifton and Lafayette Avenues, Cincinnati, Ohio.
MR. W. E. MOORE, Room 705, Union Bank Building, Pittsburgh, Pa.
PROF. I. M. RAPP, 321 West Symmes Street, Norman, Okla.
PROF. JOSEPH P. REMINGTON, 1832 Pine Street, Philadelphia, Pa.
MR. J. A. L. WADDELL, Waddell & Son, Consulting Engineers, 800 Graphic Arts Building, Kansas City, Mo.
MR. FRED H. WAGNER, Rogers Avenue and Pimlico Road, Station "E," Baltimore Md.
MR. HENRY WHARTON, Chestnut Hill, Philadelphia, Pa.
MR. J. CLIFFORD WILSON, 242 South Thirteenth Street, Philadelphia, Pa.
MR. C. H. ZEHNDER, Room 1648, 120 Broadway, New York, N. Y.

NECROLOGY.

Morris G. Condon, 1025 Hamilton Street, Philadelphia, Pa.
H. Ward Leonard, Lawrence Park, Bronxville, N. Y.
C. L. Matthews, 503 Carpenter Street, Germantown, Philadelphia, Pa.
R. P. Stout, 404 Market Street, Bethlehem, Pa.
Nathan A. Taylor, Mariner and Merchant Building, Philadelphia Pa.

LIBRARY NOTES.

ABSTRACT OF MINUTES OF THE COMMITTEE ON LIBRARY, MEETING OF SEPTEMBER 7, 1915.

The Chairman announced the death of Mr. John T. Morris, founder of the James T. Morris Memorial Fund, and Mr. Richard Gilpin, for many years a member of the committee.

On motion it was resolved

That the Committee on Library record its deep regrets at the death of these two gentlemen, the first who by his liberality established the James T. Morris Memorial Fund for the purchase of mechanical books, and the second who by long and efficient service contributed greatly to the committee's successful work.

PURCHASES.

American Electrochemical Society.—Transactions, vol. 27. 1915.
BAKER, I. O.—Treatise on Roads and Pavements. 1914.
CHILD, C. D.—Electric Arcs. 1913.
CURTIN, R. I., and JOHNSON, T. L.—Naval Ordnance. 1915.
GORGAS, WILLIAM C.—Sanitation in Panama. 1915.
KOLLER, THEODOR.—Utilization of Waste Products. 1915.
MACNUTT, J. S.—Manual for Health Officers. 1915.
MACOMBER, BEN.—The Jewel City: Panama-Pacific International Exposition. 1915.
STEIN, M. F.—Water Purification Works and their Operations. 1915.
SWINGLE, CALVIN F.—Oxy-acetylene Welding and Cutting. 1915.
WHIPPLE, GEORGE C.—The Microscopy of Drinking Water. 1914.
WHITE, CHARLES H.—Methods in Metallurgical Analysis. 1915.
WOODMAN, A. G., and NORTON, J. F.—Air, Water and Food. 1914.

GIFTS.

American Society of Agricultural Engineers, Eighth Annual Report. Madison, Wis., 1914. (From the Society.)
American Society of Mechanical Engineers, Transactions, 1914, vol. 36. New York, 1915. (From the Society.)
Association for the Prevention of Tuberculosis of the District of Columbia. Washington Health Rules. Washington, 1915. (From Mr. Emile Berliner.)

Association of Railway Electrical Engineers, Proceedings, vols. 1 to 7. Chicago, 1908–1914. (From Mr. Jos. A. Andreucetti, Secretary.)

Atchison, Topeka and Santa Fé Railway Company, Twentieth Annual Report, 1915. (From Mr. E. P. Ripley, President.)

Basin, J., Leçon de Chimie. Paris, 1901. (From Mr. N. W. Akimoff.)

Bornsen, Paul, Radium in the Light of Recent Discovery. Washington, 1915. (From the Author.)

Boston and Maine Railroad, Eighty-second Annual Report. Boston, 1915. (From the Company.)

Canada Department of Mines, Memoir 36, Geology of the Victoria and Sannich Map-Areas, Vancouver Island, B. C.; Memoir 67, The Yukon-Alaska International Boundary, between Porcupine and Yukon Rivers; Memoir 68, A Geological Reconnaissance between Golden and Kamloops, B. C., along the Canadian Pacific Railway; Memoir 78, Wabana Iron Ore of Newfoundland, The Salt Deposits of Canada, and The Salt Industry. Ottawa, 1913–1915. (From the Department.)

Carnegie Endowment for International Peace, Year Book, 1915. Washington, no date. (From the Endowment.)

Carrier Air Conditioning Company of America, Catalogue No. 13 of Carrier Air Washers and Humidifiers. New York, no date. (From the Buffalo Forge Company.)

Cleveland Engineering Society, Annual Register. Cleveland, 1915. (From the Society.)

Comision Protectora de Bibliotecas Populares, Anales de la Biblioteca, Tomo ix. Buenos Aires, 1914. (From the Comision.)

Commissioner of Patents, Annual Report, 1914. Washington, 1915. (From the Commissioner.)

Dalby, H. A., Train Rules and Train Dispatching. New York, 1904. (From Robert D. Jenks, Esq.)

Denver and Rio Grande Railroad Company, Twenty-ninth Annual Report. Denver, 1915. (From Mr. E. R. Murphy.)

Fall River Water Works, Report of the Watuppa Water Board. Fall River, Mass., 1915. (From the Water Works.)

I inlande l'Administration générale de l'industrie, Teollisuushallituksen Tiedonantoja, Meddelanden fran Industristyrelsen I Findland. Helsingfors, 1915. (From the Administration Generale.)

Hirsch, M., Die Luftpumpen, parts i and ii. Hanover, 1905. (From Mr. N. W. Akimoff.)

Illinois Society of Engineers and Surveyors, Incorporated, Thirtieth Annual Report, 1915. Wheaton, no date. (From the Society.)

International High Speed Steel Company, Catalogue of Mining and Rock Drill Steel. New York, no date. (From the Company.)

International Library of Technology, vols. 73 and 74. Scranton, Pa., no date. (From Mr. N. W. Akimoff.)

International Railway Fuel Association, Proceedings, 1911–1915. Chicago, 1911–15. (From Mr. C. G. Hall, Secretary.)

Iron and Steel Institute, Journal, No. 1, vol. xci. London, 1915. (From the Institute.)

Leland Stanford Junior University, Register, 1914–15. Stanford University, Calif., 1915. (From the University.)

Link-Belt Company, General Catalogue No. 110. Philadelphia, no date. (From the Company.)

Madison Water Commission, Thirty-second Annual Report, 1914. Madison, Wis., 1915. (From the Commission.)

Marchena, R. E. de, Machine Frigorifiques. Paris, no date. (From Mr. N. W. Akimoff.)

Medart Patent Pulley Company, Catalogue of Power Transmitting Appliances. St. Louis, no date. (From the Company.)

Metropolitan Water and Sewerage Board, Fourteenth Annual Report, 1914. Boston, 1915. (From the Board.)

Michigan College of Mines, Year Book, 1914–15. Houghton, no date. (From the College.)

Minneapolis, St. Paul and Sault Ste. Marie Railway Company, Twenty-seventh Annual Report. Minneapolis, 1915. (From the Company.)

Missouri Botanical Garden, Annals, vol. ii, No. 3. Missouri, 1915. (From the Trustees of the Botanical Garden.)

Musil, A., Die Motoren für Gewerbe und Industrie, und Wärmemotoren. Braunschweig, 1897 and 1899. (From Mr. N. W. Akimoff.)

New York, Ontario and Western Railway Company, Thirty-sixth Annual Report. New York, 1915. (From the Company.)

New York University, Theses: The Genesis of Certain Paleozoic Interbedded Iron Ore Deposits, by Raymond B. Earle; A Dissertation on the Development of the Science of Mechanics, by David H. Ray; The Densities of Certain Dilute Aqueous Solutions by a New and Precise Method, by Richard E. Lee; and five pamphlets on various subjects. New York, 1904–1914. (From the Librarian.)

New Zealand Institute, Transactions and Proceedings, vol. xlvii, 1914. Wellington, 1915. (From the Institute.)

North Carolina Geological and Economic Survey, Economic Paper No. 40, Forest Fires in North Carolina during 1914; Economic Paper No. 42, Organization of Coöperative Forest-fire Protective Areas in North Carolina. Raleigh, 1915. (From the Survey.)

North of England Institute of Mining and Mechanical Engineers, Annual Report of the Council, 1914–15. Newcastle-upon-Tyne, 1915. (From the Institute.)

Ohio University, Catalogue, 1915–16. Athens, 1915. (From the University.)

Philadelphia Bureau of Gas, Report, 1914. Philadelphia, no date. (From Mr. Judson C. Dickerman, Chief.)

Ruud Manufacturing Company, Handbook of Gas Water Heaters. Pittsburgh, 1915. (From the Company.)

Seydel's Führer durch die neuere deutsche technische Litteratur. Berlin, 1898. (From Mr. N. W. Akimoff.)

Standard Machinery Company, Catalogues of Rolling Mills, Drop Presses, Power Press and Miscellaneous Machinery. Providence, R. I., no date. (From the Company.)

State College of Washington, Catalogue. Olympia, 1915. (From the College.)

Sturtevant, B. F., Company, Catalogue No. 215, Heating and Ventilation. Boston, no date. (From the Company.)

Tufts College, Catalogues, 1901 to 1915. Tufts College, Mass., no date. (From the College.)

Tulane University of Louisiana, Registers, 1911 to 1915. New Orleans, La., no date. (From the University.)

Union Chain and Manufacturing Company, Catalogue No. 3 of Steel Chains. Seville, Ohio, no date. (From the Company.)

U. S. Army, Index Catalogue of the Library of the Surgeon-General's Office, vol. xx, Second Series. Washington, 1915. (From the Surgeon-General's Office.)

Universal Portland Cement Company, Concrete for the Farmer; Concrete in the Barnyard; Concrete Pavements, Sidewalks, Curb and Gutter; Concrete Silos; Small Farm Buildings of Concrete; Concreting in Cold Weather; Small Concrete Bridges and Culverts; Proceedings of Conference on Permanent and Sanitary Farm Improvements; Concrete Surfaces; Farm Cement News. Chicago, 1913–14. (From the Company.)

University of Illinois, Register, 1914–15. Urbana, no date. (From the University.)

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University of Utah, Catalogue, 1914–15. Salt Lake City, no date. (From the University.)

University of Wisconsin, Catalogues, 1913–14, 1914–15. Madison, 1914, 1915. (From the University.)

Uruguay Anuario Estadistico, vol. xxiii, 1911 and 1912. Montevideo, 1915. (From the Director General de la Statistique.)

Weinstein, B., Thermodynamik und Kinetik der Körper. Braunschweig, 1901. (From Mr. N. W. Akimoff.)

BOOK NOTICES.

SURFACE TENSION AND SURFACE ENERGY, by E. S. Willows and E. Hatschek. Philadelphia, P. Blakiston's Son & Company, 1915. 80 pages, illustrations. Price, $1.

Many years ago the great Belgian chemist, Prof. W. Spring, of Liège, who had a rare talent for obtaining unexpected and important results by very simple experiments, found that when a crystal of calcite is partially immersed in hydrochloric acid the action is most rapid at the surface, so that the crystal is cut in two pieces. The same thing occurred when a sugar crystal was suspended in water. Since these early observations, facts which demonstrate that the surface of a liquid may, under proper conditions, behave in a different manner from the interior have accumulated. Solutions are now known in which practically the whole of the solute accumulates in the surface

film. This, in very dilute solution, is the case with such familiar substances as salicylic acid and the soaps.

Striking facts like these, whose interest to the chemist, the physicist, and the biologist is obvious, furnish a sufficient reason for a simple and intelligible treatment of the difficult subject of surface energy. However, from a somewhat different point of view the book is welcome. The scientific and practical importance of the colloidal state is increasing at a wonderful rate. We consist of colloids, exist by consuming them, and nowadays almost everybody wants to have them explained to him. But a colloid system may be roughly defined as a state in which subdivision has gone so far that surface energy has assumed the chief rôle and has relegated gravitation, cohesion, etc., to the background, so that the book has an intimate connection with the subject of colloids, though it does not avowedly treat of them.

The reviewer has nothing but commendation for this little volume. Clearness and accuracy prevail throughout. The treatment is almost nonmathematical, and the chemists, for whom it seems to be intended, will be able to use it without much difficulty and to great advantage.

ROBERT H. BRADBURY.

U. S. BUREAU OF MINES BULLETIN 94. United States Mining Statutes Annotated by J. W. Thompson. Part I, Sections and Statutes Relating to Metalliferous and Coal Mining. Part II, Miscellaneous Mining Subjects. Two volumes, 8vo. Washington, Government Printing Office, 1915. Price $2.50.

The Bulletin is intended for persons engaged in mining enterprises that come within the scope of the Federal mining laws, and as a guide in the determination of mining rights and duties. It shows the status of every Federal law relating to mining, those relating to metal mining as well as those relating to coal, oil and phosphate, and to mining on public, Indian, and railroad lands. The work includes also references to Alaska and the Philippine Islands.

PUBLICATIONS RECEIVED.

U. S. Bureau of Standards: Technologic Paper, No. 48, An Air Analyzer for Determining the Fineness of Cement, by J. C. Pearson, Assistant Physicist, and W. H. Sligh, Aid, Bureau of Standards. 74 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Mines: Bulletin 75, Rules and Regulations for Metal Mines, by W. R. Ingalls, James Douglas, J. F. Finlay, J. Parke Channing, and John Hays Hammond. 296 pages, 8vo. Bulletin 101, Law Serial 5, Abstracts of Current Decisions on Mines and Mining, October, 1914, to April, 1915, by J. W. Thompson. 138 pages, 8vo. Monthly Statement on Coal-mine Fatalities in the United States, July, 1915, compiled by Albert H. Fay. 16 pages, 8vo. Washington, Government Printing Office, 1915.

Eastman Kodak Company: Abridged Scientific Publications from the Research Laboratory, 1913–1914. 76 pages, illustrations, 8vo. Rochester, N. Y., Eastman Kodak Company, no date.

New York Public Library: New Technical Books. A Selected List on Industrial Arts and Engineering Added to the New York Public Library, June to August, 1915. 28 pages, 8vo. New York, N. Y., Public Library, 1915.

U. S. Department of Agriculture: Bulletin 284, Construction and Maintenance of Roads and Bridges from July 1, 1913, to December 31, 1914. 64 pages, 8vo. Washington, Government Printing Office, 1915.

Potts, Rufus M.: Protecting Congested Districts in Cities. Address delivered by Rufus M. Potts, Insurance Superintendent of Illinois, before the National Convention of Insurance Commissioners, Monterey, Calif., September 22, 1915. 9 pages, 8vo. Springfield, Ills., State Printers, 1915.

Cooling Ponds for Condensing Engines. L. H. PARKER. (*Proceedings of The National Association of Cotton Manufacturers,* September 9 to 11, 1915.)—Spray cooling pond systems under average conditions have lowered first cost, require less power for operation and practically no maintenance as compared with cooling towers, and they are being used to a constantly increasing extent in connection with cotton mills, except in cases when sufficient pond area is not available, either on the ground or on the roofs of buildings adjacent to the condensing installation.

Some mills of comparatively small capacity are now operated non-condensing, due to the lack of a sufficient supply of cool water. Many of these mills could install an earthen pond or a concrete basin at small expense and thus make a net saving in power cost of 15 to 20 per cent.

In addition to a number of other economic advantages, the first cost of spray systems including ponds generally averages one-half the cost of cooling towers of similar capacity and of good design and construction.

Slush Castings. G. RIGG and H. C. MORSE. (*Proceedings of the American Institute of Metals,* September 28 to October 1, 1915.)—The process of slush casting is used quite extensively in the manufacture of various ornamental objects. Hollow and therefore relatively light castings are produced by pouring the metal into the mould until full and immediately pouring out again what remains liquid, leaving a thin-walled casting chilled upon its inside surface. The mould is usually mounted upon trunnions or otherwise arranged to facilitate its rapid emptying. The moulds are of metal, usually bronze or brass, which can be machined easily and will not be injured by the molten metal. Zinc with small percentages of impurities, commonly cadmium, lead, iron, and arsenic, known as spelter, is employed for the castings.

CURRENT TOPICS.

The Difficulties of Color Cinematography. ANON. (*British Journal of Photography*, vol. lxii, No. 2891, October 1, 1915.)—It is obvious that the most satisfactory solution of the problem of producing films in color would be one in which the colors exist in the film itself, as they do in screen plates or in transparencies formed by some process akin to three-color carbon. Screen-plate methods, however, present almost insuperable difficulties when applied to cinematograph films. To say nothing of the cost, which is a very serious item, there are great troubles due to the extreme delicacy and fragility of all such screen films, and also inventors have to cope with the enormous magnification to which cinematograph pictures are subjected that renders anything but a screen of the finest possible grain almost useless. Lack of sufficient transparency is also a trouble, and a prohibitive one in the case of screens that approach the density of the Autochrome. Methods akin to the three-color carbon process also present great difficulties, even if we reduce the three colors to two. In addition to the technical difficulties of printing such films, we have a new trouble of securing two or three separate negatives. The same trouble exists when we attempt to apply the additive three-color projection process or a two-color equivalent, such as the "Kinematicolor," and this trouble is due to the effects of parallax, which must exist if the several negatives are not produced at the same instant and from exactly the same standpoint.

In ordinary three-color photography this difficulty has necessitated the invention of what are called one-exposure cameras, in which one lens is used and the light transmitted by it is split up by mirrors, so that three separate images are simultaneously produced, each through its own color screen. Such cameras require very delicate adjustment, and a cinematograph designed on the same principles would be both delicate and complex. Moreover, the splitting up of the light by reflectors lowers its intensity on each image.

The only method that is in practical use at the present time is "Kinematicolor," a two-color method, with which persistence of vision is relied upon for the visual combination of alternate images projected in red and green respectively. In this method the different phases of movement represented by the different images prevent perfect combination when the movement depicted is a rapid one, but the process gives excellent results so long as the movement is not too rapid. Though the method is only a compromise and not an ideal solution of the problem, its popular success shows that a perfect solution is quite worth while achieving.

Experiments with Natural and Illuminating Gas. (*Technical Paper No. 104, United States Bureau of Mines.*)—This publication is one of a series dealing with the increase in efficiency in the production and utilization of fuels. Fractional distillation in a vacuum at low temperatures is employed in the experiments. The gas is liquefied, the different constituents separated by proper adjustment of temperature, the various fractions removed with a mercury pump and these fractions analyzed by ordinary slow-combustion methods. The method was successfully applied to the separation of hydrocarbons in natural gas and in artificial illuminating gas, and is the only known method applicable to the separation of some hydrocarbons.

The first part of the report describes the results of experiments by which the natural gas used in Pittsburgh, Pa., was separated into its individual paraffin hydrocarbons. The second part describes experiments in which the separation of the illuminants in artificial illuminating gas of Pittsburgh and New York City was effected. Some experiments to determine the practicability of separating gases whose boiling-points lie close together, such as ethane and ethylene, are included.

Cutting Aluminum Rapidly on a Buzz Planer. ANON. (*American Machinist,* vol. 43, No. 16, October 14, 1915.)—One of the most striking innovations seen in a machine shop in many years is the use of a buzz planer for surfacing the aluminum oil pans which go under the engine crank case of a Curtis aëroplane motor. This was done in the shop of the Herschell-Spillman Company, North Tonawanda, N. Y., not simply as a revolutionary innovation, but to solve a problem not easily met in any other way.

There were 150 crank cases or oil pans to surface, and the walls were only ⅛ inch thick—very light to hold in an ordinary fixture so as to withstand the stresses of cutting and clamping without distortion. So the buzz planer was tried and with excellent results.

Although it required from six to eight cuts to remove the 1/16-inch metal necessary, the average time for each casting was less than 10 minutes. This and the saving of expense for fixtures made it a low-cost operation.

The entire 150 pans were surfaced in this way, the regular buzz-planer knives surfacing an average of 35 oil pans between each sharpening of the knives, which left a good surface on the pans.

Aluminum has offered opportunities for many experiments in high-speed cutting, the limiting factor often being the ability to hold the work and resist the cutting stress without distortion. In a number of cases 150 feet cutting speed for aluminum is being regularly used, and, while this has by no means been considered the limit of the cutting tool, other factors have seemed to make it the practical limit. It does not seem impossible that a modification of the high speed and light cut of the buzz planer may yet be made to apply to the harder substances.

Many Carbon-free Metals and Alloys Now Available. H. DEC. BROWNE. (*Engineering News,* vol. 74, No. 14, September 30, 1915.)—Manganese, chromium, and cobalt 97 to 99 per cent. pure, and carbon-free alloys of these and other elements, such as vanadium and titanium, are now readily procurable. In many metallurgical operations there is need of employing carbon-free metals and alloys in order to control fully the physical properties of the final metal, which may be a special steel or bronze, for instance. A large number of these have been developed by the Goldschmidt Thermit Company of New York City, employing in their production the well-known aluminum-oxidation reaction by which a high temperature is produced in carbon-free surroundings.

A Possible Substitute for Acetylene in Welding and Cutting. J. F. SPRINGER. (*Railway Age Gazette,* Mechanical Edition, vol. 89, No. 10, October, 1915.)—Ordinary natural gas consists largely of methane, the heating value of which is low in comparison with acetylene. At Follansbee, W. Va., a natural gas is produced which contains no methane and is made up of approximately four-fifths propane and one-fifth ethane. This gas has a thermal value of 2468 B. T. U. per cubic foot. Experiments with this gas at various stages of compression indicate that the constituents of higher thermal value are first liquefied, leaving the others in the residual gas. When subjected to 400 pounds pressure per square inch at 32° F., and revaporized, a gas of varying quality was obtained. Of several samples taken at regular intervals, one was almost pure ethane, another almost pure propane. The lowest thermal value was 1808 B. T. U., and the highest, 2621 B. T. U. per cubic foot. The methane which has the lowest heating value (1065 B. T. U.), and is therefore the least desirable in the semi-liquid product, requires a pressure of 2700 pounds per square inch to cause it to liquefy, and is therefore not apt to be present in the product of compression under 400 pounds per square inch.

From another set of experiments with Follansbee gas under 400 pounds pressure, it was found that samples drawn from the top of the same cylinder varied considerably in quality and heating value. It was found, however, that by drawing the supply for the torch from the bottom a gas of approximately uniform quality may be obtained. Its boiling-point is –40° F., and at 32° F. it requires a pressure of 400 pounds to maintain it in a liquid state. At 131° the pressure is 755 pounds, which is well within the practice of handling similar products. If higher temperatures are apt to be met it will not be difficult to secure containers to withstand the higher pressure.

The new gas seems to have originated through the development of natural gas gasoline, which was first obtained by simply collecting the liquid formed by condensation in pipes transmitting natural gas. The next step was artificial chilling of the pipes, followed by low-pressure, single-stage compression, and later of carrying the raw gas through two stages of compression.

A Novel Design in Gas Holders. ANON. (*The Times* (London) *Engineering Supplement*, No. 491, September 24, 1915.)—Since the early days of gas lighting the floating bell or "balloon" principle has without exception been adopted in the design of gas holders, although various schemes for the guidance of the bell during its upward and downward travel have from time to time been introduced. Perhaps the most striking departure from the stereotyped design was witnessed with the spiral holder, in which separate guide framing was discarded altogether. So far as originality is concerned, however, the new "floating roof" holder (hailing from Nuremberg) demands a certain amount of attention.

The principle employed permits the expensive water tank (always associated with the common type of holder) to be dispensed with altogether, although gas-tightness is insured by the use of water seals as heretofore. Simply explained, the holder consists of an outer cylindrical shell very similar in construction and appearance to the present holder bell, but with the exception that no movement is permitted. The contrivance is, in fact, little more than a cylindrical tank, the roof of which, by means of guide rollers, is permitted to rise and fall within the tank. Gas is admitted in the ordinary way beneath the roof, which ascends and descends in accordance with the prevailing pressures in the interior. The guidance of the floating dome is such that the smallest amount of clearance is permitted between it and the internal periphery of the cylinder: hence the space available for gas escape is reduced to a minimum. The means employed for the prevention of all leakage is, however, novel, and consists in pumping water upon the exterior of the dome so that it runs down to the portions above the guide rollers and seals up the clearance between cylinder and dome. Some portion of the water is, of course, continuously passing through this clearance into the interior of the holder, whence it is removed by way of a seal and returned to the suction of the pump. The last-named is so regulated that the quantity of water delivered to the exerior of the crown is just sufficient to replace the wastage into the interior. Thus the flexible but gas-light joint is constantly maintained.

So far as capital outlay is concerned, the new holder possesses undoubted advantages and, providing no difficulties are met with in practice, should prove of especial utility in the smaller works. A feature that must not be overlooked, moreover, is the readiness with which the pressure may be adjusted by regulating the quantity of water carried by the crown.

New Krupp Armor Plates. ANON. (*Scientific American*, vol. cxiii, No. 16, October 16, 1915.)—During the past year the Krupp works at Essen have perfected a new kind of armor plate that has a far greater power to resist the penetration of projectiles than any heretofore produced. But, although these plates are extremely valuable for the protection of ships of war, a wide application is antic-

ipated for them in the building of safes. Not only are the plates so extremely hard that they cannot be drilled, but they have a remarkable resistance to the flame of an oxyacetylene lamp. It is estimated that to burn a hole three inches in diameter and ¾ inch thick would require six hours and the consumption of 350 cubic feet of oxygen and 320 cubic feet of acetylene.

Recent Developments in Light Signal for Control of High-speed Traffic. J. E. SAUNDERS. (*The Electric Journal,* vol. xii, No. 10, October, 1915.)—The most recent development in light signalling is the position light signal now in operation on the Pennsylvania Railroad between Broad Street Station, Philadelphia, and Paoli, Pa. The basic principle embodied in the development of this signal is that indication both by day and by night shall be independent of color. Indications by this signal are given by the illumination of any one of three rows of lamps extending either horizontally, at an angle of 45 degrees, or vertically. The minimum daylight range is approximately 3000 feet.

Probably the first twenty-four-hour light signal had a daylight range of one hundred feet or less and was used for the control of a trolley car. About two years ago experiments were conducted in the laboratories of the Union Switch and Signal Company to determine the value of the application of concentrated filament lamps to light signals. Very quickly the range of 500 feet in 1910 became 2000 feet, and, with further improvements in lens arrangement, minimum daylight ranges of 3000 feet were made possible. At the same time the voltage of the lamps was steadily reduced until at the present time signal indications are conveyed in bright sunlight with an expenditure of only 20 watts.

Tests of Lenses for Foundry Goggles. F. W. KING. (*Proceedings American Foundrymen's Association,* September 28 to October 1, 1915.)—To meet the requirements for goggles in foundry operations provided with lenses that will not shatter when struck, manufacturers have developed optical glass that not only meets the most rigid specifications, but which will withstand a more severe test than that prescribed by any user. The Illinois Steel Company has designed a drop-test machine for testing lenses which is equipped with a support for the goggles. A steel ball ⅝ inch in diameter, weighing 16.25 grammes, is dropped from a height of 21 inches upon the lens, which must withstand 15 blows without breaking or cracking. From a shipment of a gross or more of goggles, 25 per cent. of one dozen are selected at random for this test. If any of the six lenses fails in the test, the entire shipment is rejected.

A lens has been developed which can successfully withstand the impact of a 9-ounce ball, 1½ inches in diameter, as compared with the 1-ounce ball specified.

Artificial Daylight for the Microscope. S. H. GAGE. (*Science*, vol. xlii, No. 1085, October 15, 1915.)—Until very recently all the efforts to make a light filter or screen for artificial light which would transmit light having daylight qualities by which colors could be detected and discriminated with the same certainty as in daylight were unsuccessful.

During the last two years Dr. Henry Phelps Gage, working in the laboratories of the Corning Glass Works, with the facilities there found, has developed a glass filter which renders the light from a nitrogen-filled tungsten lamp almost exactly like daylight. The light approaches very closely that of sunlight, especially in the region of the visible spectrum giving the greatest amount of useful light.

Light filtered through the daylight glass has been very critically tested on microscopic objects stained with many different dyes. The tests were made in the daytime by a window so that it was possible to turn the mirror from artificial daylight to true daylight instantly. In the hands of several observers no differences in color could be detected in all the tests made with varied subjects.

The glass was tested with other light sources used in microscopic work, viz., the vacuum tungsten and carbon filament lamps, illuminating gas with Welsbach mantle, acetylene, and, finally, the flat-wick kerosene lamp. None of these other sources gave exactly the same color values as daylight. However, the approximation to daylight was surprisingly good, and the worst one, the kerosene flame, gave better color values than the best artificial light without the color screen.

The Development of the Army Pistol. E. C. CROSSMAN. (*Scientific American*, vol. cxiii, No. 14, October 2, 1915.)—The main function of a pistol in warfare is to immediately dispose of an antagonist before he can harm the possessor of the weapon. It is far better to eliminate the foe as a fighting force, even temporarily, than to inflict a fatal wound—fatal hours later, but not immediately disabling. Time is the essential feature; it is what the other man does the first ten seconds after being hit that determines whether or not the arm is an efficient arm. All this because the range is no longer in inches than the ordinary range of the rifle fight is in yards.

Owing to the absolute necessity of immediately eliminating the foe—delivering a crumpling blow of the bullet on one who may be threatening the possessor of the pistol with almost certain death—the United States Government has adopted the 0.45 calibre with a ponderous 230-grain bullet. The velocity is but 800 feet per second, less than a third that of the army rifle, while the bullet weighs 50 per cent. more than that of the rifle. Range, trajectory, remaining energy at a mile, none of these things count when the mark is but a few feet away.

Those nations that have carried on warfare with savages fully appreciate the value of large calibred pistols. The British, after

various encounters with the hill men of India, evolved a generous bullet of 0.455 calibre for their service revolvers. Their officers went even further and adopted a double-barrelled pistol taking either huge slugs or a number of buckshot. These pistols were usually of 20-gauge in shotgun measurement, which in inches is 0.615 calibre, smooth bored. These huge 0.61 slugs usually proved amply effective in use.

The United States Army discarded the old, single-action, 0.45-calibre revolver in the '90's and adopted a 0.38-calibre, double-action revolver. Then came the conquest of the Filipino insurgents, in which the revolver as a weapon was largely employed. The experience of the American soldiers engaged was precisely that of the British; namely, the larger the calibre, the better the results, and the 0.38-calibre was voted ineffective. So there is considerable satisfaction with the present gun of the American forces, the 0.45-calibre automatic Browning pistol, with its eight shots, its compact form, ease of taking apart, and certainty of function.

The other nations lacking the practical experience of the Americans along a western frontier, and the British in their various and never-ceasing arguments along the Indian frontier, favor smaller calibres in their pistols than we regard as being practical. The 9-mm. or 0.36-calibre appeals to them as adequate. None of the nations now at war has adopted the 0.45-calibre in its automatic pistols, but doubtless they will know better when the war is over.

Gas-Electric Locomotives for "Dan Patch" Line. ANON. (*Electric Railway Journal*, vol. xlvi, No. 14, October 2, 1915.)—The Minneapolis, St. Paul, Rochester, and Dubuque Electric Traction Company, operating what is popularly known as the "Dan Patch" electric line, has recently placed in commission three 60-ton gas-electric locomotives for freight, passenger, and terminal service. This line is said to be the first railroad to be operated entirely with gas-electric service. The locomotives are double-ended, being built with the box type of cab extending nearly the entire length of the underframe. The wheels are 33 inches in diameter, and each locomotive is equipped with four 100-h. p. motors.

Each of the two gas-electric generating sets for the power plant equipment is composed of a 175-h. p., 550-r. p. m., 8-cylinder, 4-cycle gasoline engine of the "V" type which is direct-connected to a 600-volt, commutating pole, compound wound electric generator. The cylinders are 8 inches bore and 10 inches stroke. Ignition is accomplished with low-tension magnetos, and the sets are started by air-pressure in the same way as in the gas-electric motor cars, with the additional feature that when one set is running, the other may be started electrically from the first. The control is so arranged that either one or both of the generating units may be used to operate the locomotive from either end.

Nickel-plating Aluminum. ANON. (*La Chronique Industrielle*, 38th year, No. 224, September 1, 1915.)—A process of nickel-plating aluminum, invented by M. J. Carnac, which is claimed to produce a firmly-adhering coating, is described in *Ind. e Inv.*, Barcelona.

The aluminum is first cleaned in a bath of boiling potash; it is next brushed with milk of lime and then immersed into a bath of potassium cyanide for several minutes; finally it is subjected to the action of a bath of ferrous chloride, composed of 500 grammes of hydrochloric acid, 500 grammes of water, and 1 gramme of iron. After each operation the object is washed in clear water.

Good results are obtained from a plating bath composed of water, 1000 c.c.; chloride of nickel, 50 grains; boric acid, 20 grains; with a current of 1 ampère per square decimetre at 2.5 volts. The good results of the process appear to depend upon the perfect cleaning and a suitable deposition on the aluminum of a thin coating of iron from the iron bath. The existence of this thin coating is verified by comparing with a magnetic balance a treated and an untreated specimen of aluminum.

Under these conditions the nickel deposit infiltrates through the surface of the aluminum and adheres so thoroughly to it that, however heavy the deposit, it is impossible to detach the nickel without removing particles of aluminum.

Use of a Small Cooling Tower for Transformer Circulating Water. ANON. (*Electrical World*, vol. 66, No. 15, October 9, 1915.)—The very considerable total loss of energy which takes place even in such high-efficiency apparatus as electric transformers may be well appreciated from the arrangement of the water-cooling service for the transformer at a new sub-station of the East St. Louis Light and Power Company. The practice at this station is that of cooling and recirculating the transformer cooling water in a miniature cooling tower. Water is pumped through two large transformers at the rate of about 100 gallons per minute by a 5-horse-power motor. The fact that water purchased from the city is used for cooling the transformers made the installation of the cooling system profitable.

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COMMITTEE ON SCIENCE AND THE ARTS. First Wednesday of each month, 8 P.M. (except July and August).

BOARD OF MANAGERS. Second Wednesday of each month, 3.30 P.M.

INSTITUTE. Third Wednesday of each month (except June, July, August and September), 8 P.M.

SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

	PAGE
Officers for 1915	xii
Membership	xiii
Awards and Premiums	xiv
Elliott Cresson Medal	xv
John Scott Legacy, Medal and Premium	xvi
Boyden Premium	xvii
Howard N. Potts Gold Medal	xviii
Edward Longstreth Silver Medal	xviii
Library	iv, xxi
Journal and Indices	xxi
School of Mechanic Arts	xxii

CHANGES OF ADDRESS

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R. B. OWENS
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